AD-A190 203 SOFTWARE SUPPORTABILITY RISK ASSESSMENT IN OT&E (OPERATIONAL TEST AND EVA..(U) BDM CORP ALBUQUERQUE NM D E PEERCY ET AL. 07 OCT 85 BDM/A-85-0510-TR-VOL-1 1/3

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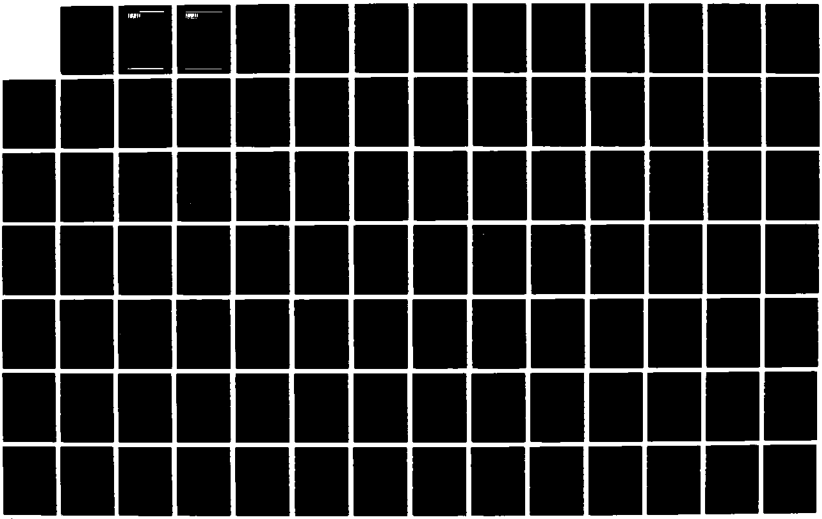


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Software Supportability Risk Assessment in OT&E: Historical Baselines for Risk Profiles

Volume I

DISTRIBUTION: UNLIMITED

October 7, 1985

BDM/A-85-0510-TR

BDM

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A-1

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: N/A

1b. RESTRICTIVE MARKINGS: None

2a. SECURITY CLASSIFICATION AUTHORITY: N/A

2b. DECLASSIFICATION/DOWNGRADING SCHEDULE:

3. DISTRIBUTION/AVAILABILITY OF REPORT: Unlimited

4. PERFORMING ORGANIZATION REPORT NUMBER(S): BDM/A-85-0510-TR

5. MONITORING ORGANIZATION REPORT NUMBER(S):

6a. NAME OF PERFORMING ORGANIZATION: The BDM Corporation

6b. OFFICE SYMBOL (If applicable):

7a. NAME OF MONITORING ORGANIZATION: Air Force Operational Test and Evaluation Center/RMC

6c. ADDRESS (City, State and ZIP Code): 1801 Randolph Rd, SE, Albuquerque, NM 87106

7b. ADDRESS (City, State and ZIP Code): Kirtland Air Force Base, NM 87117-5000

8a. NAME OF FUNDING/SPONSORING ORGANIZATION: Same as 7a

8b. OFFICE SYMBOL (If applicable): LG5T

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: F29601-80-C-0035

8c. ADDRESS (City, State and ZIP Code): Same as 7b

10. SOURCE OF FUNDING NOS.

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.
SS 327/04		4.1	

11. TITLE (Include Security Classification): Software Supportability Risk Assessment in OT&E:

12. PERSONAL AUTHOR(S): D. Peercy, W. Huebner, M. Estill, J. Wu

13a. TYPE OF REPORT: Technical

13b. TIME COVERED: FROM 11/19/84 TO 10/07/85

14. DATE OF REPORT (Yr., Mo., Day): 85/10/07

15. PAGE COUNT: 300

16. SUPPLEMENTARY NOTATION:

17. COSATI CODES

FIELD	GROUP	SUB. GR.

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Assessing the software supportability risk of Air Force acquired systems is necessary to enable various decision makers to properly plan for system deployment. Risk assessment (RA) is required throughout the system acquisition life cycle. Since the perspective of OT&E is focused upon the overall system mission, including supportability, methods are required which point software testers to areas which require testing emphasis and which provide decision makers with an assessment of software and software support risk for production decisions. Due to the complexity of these requirements, it is necessary to develop and implement a risk assessment methodology of software supportability with the proper system mission perspective to ultimately assist the top level decision maker.

In the assessment of risk, the first criteria to establish are the baselines against which to measure the risk. This report contains the results of a study which collected software support activity data from a variety of DoD software support facilities and

over

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☒ DTIC USERS ☐

21. ABSTRACT SECURITY CLASSIFICATION: UNCLASSIFIED

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22c. OFFICE SYMBOL: AFOTEC/LG5T

Item 11 (cont'd):

Historical Baselines for Risk Profiles (Volumes I and II)

Item 19 (cont'd):

systems. The data collected was used to develop historical profiles of the activities observed. These profiles are the risk baselines against which negative outcomes can be determined from evaluations of software support risk.

FOREWORD

a. This technical report, BDM/A-85-0510-TR, is submitted by The BDM Corporation, 1801 Randolph Road, S.E., Albuquerque, New Mexico 87106, to the Air Force Operational Test and Evaluation Center, Kirtland Air Force Base, New Mexico, 87117. This report is in compliance with CDRL Item A008, Contract F29601-80-C-0035, and fulfills the requirements of paragraph 7.3 of Subtask Statement 327/04, titled "Risk Profile Development for Software Supportability."

b. This report is the result of effort by Mr. Walter Huebner, Jr. (Task Leader), Dr. David Peercy (Technical Leader), Mr. M. Donan Estill, Jr. and Ms. Jean C. Wu of The BDM Corporation. The primary Subtask Statement Project Officer is Capt. Eric H. Tomlin (AFOTEC/LG5T); the alternate Subtask Statement Project Officers are Maj. Gary R. Horlbeck (AFOTEC/LG5T) and Mr. Jim M. Baca (AFOTEC/LG5).

Reviewed and approved by:

Walter F. Huebner
Walter F. Huebner
Program Manager

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I. Introduction

SECTION I

INTRODUCTION

1.1 BACKGROUND.

a. The Air Force Operational Test and Evaluation Center (AFOTEC) has the responsibility for conducting operational test and evaluation (OT&E) of assets entering the Air Force inventory. AFOTEC has developed and implemented various software OT&E methodologies. These methods have matured and have become the Air Force standard for evaluating software supportability. Each of these developed methods evaluates specific characteristics of the supportability aspects of delivered software and software support resources. These stand-alone evaluations provide AFOTEC with information to identify particular software supportability deficiencies, but do not identify overall risk associated with contractor or military ownership and organic maintenance of contractor-delivered software.

b. Assessing the software supportability risk of Air Force acquired systems is necessary to enable various decision makers to properly plan for system deployment. Risk assessment (RA) is required throughout the system acquisition life cycle. The perspective of OT&E is focused upon the overall system mission operation, including support. Methods are needed to point software testers to areas that require testing emphasis, and provide decision makers with an assessment of the software supportability risk.

c. Since major weapon systems are using more sophisticated computer applications, software support for these systems is becoming an increasingly greater cost factor in overall system cost. Furthermore, when many enhancements to a system are dependent on software modifications, the timeliness of such software support is critical to system operational availability and effectiveness. Because of this

criticality of the software support function to overall system mission operational capability, it is desired that top decision makers be aware of the risk associated with the software supportability of a system at specific points during the system development cycle, but in particular at the conclusion of OT&E.

d. In order to determine this risk during OT&E, AFOTEC initiated the development of a risk assessment methodology of software supportability with emphasis on system mission. This approach was taken to provide more meaningful information to top level decision makers than had previously been available. In 1983, AFOTEC produced a concept proposal (reference 8.7) for computer resources risk assessment during operational test and evaluation. This effort integrated an approach, appropriate models, and subjective and quantitative software operational and supportability measures into a management-oriented assessment of user and supporter risk. This initial involvement with the application of risk assessment to software supportability provided AFOTEC with justification to support a study of the feasibility of development and implementing a risk assessment methodology for software supportability (RAMSS). The feasibility study (reference 8.8) proposed a conceptual RAMSS which incorporated a theoretical foundation for risk assessment with the software evaluation tools presently being used by AFOTEC. The risk assessment methodology represents the authors' determination of the most practical way to assess risk under the criteria and constraints with which AFOTEC must work and the software evaluation process in general. The results of the feasibility study are reported in references 8.1, 8.2, and 8.3.

e. Given that the feasibility study demonstrated the merit of implementing the proposed RAMSS, the next logical step in the development of the model has been to gather and analyze data on software support activities for systems of interest to the Air Force, and develop a basis from which measurement of risk can be made. This

report documents the results of the data collection and analysis step.

1.2 STUDY OBJECTIVE.

a. The overall objective of this task study, as stated in Subtask Statement 327/00 (reference 8.0) was "to develop historical profiles of software support activities from USAF software support facilities. These profiles shall provide AFOTEC with baselines against which evaluations of software support risk can be developed." Various types of data and information have been collected from approximately 80 major weapons systems and subsystems during this study. These data have formed the basis for the development of historical profiles, or "baselines," from which risk can be measured. These profiles are presented in section V of this report.

b. While the above objective is satisfied in this report, there are other benefits which are fallouts of the process of performing the study and collecting the data. These other benefits include:

(1) An understanding of the kinds of software maintenance activity data available at Air Force software support facilities

(2) Development of a survey format that will be used to set a standard for collecting software maintenance activity data from other systems or from the same systems in future data collection efforts

(3) A study of how the types and availability of expected software maintenance activity data affect the applicability of the recommended RAMSS

(4) As a result of collecting the data from different locations, a common information data base has been formed from which implications of systemic improvements to software maintenance support activities may be inferred, with an eye toward improving overall capabilities Air Force or DoD-wide.

1.3 REPORT ORGANIZATION.

a. The remainder of this report is organized into seven additional sections, plus a set of appendices that include detailed information supporting the results of this study. Report sections satisfy the following objectives:

(1) Section II contains an executive summary of this study, and a technical summary which includes an overview of the approach, a summary of the analysis conducted, an historical profile example, a review of the methodology, and conclusions/recommendations from this study.

(2) Section III contains a general discussion of the approach taken in performing this study. Specific topics include assumptions concerning the software maintenance activity, the site survey format, facility visit procedures, a list of the facilities visited and systems examined, and a recommended maintenance data collection form for software support sites.

(3) Section IV describes results from data analyses.

(4) Section V contains the historical profiles: one for all systems, and other profiles by site, and by system type.

(5) Section VI briefly describes the RAMSS and gives an example of how to use the historical profiles to predict software supportability risk.

(6) Section VII contains a discussion of the conclusions and recommendations from this study.

(7) Section VIII lists the documents whose contents have formed the basis for this report.

(8) Appendix A lists acronyms used in this report.

(9) Appendix B is a glossary of terms used in this report.

(10) Appendix C is the final version of the site survey format recommended for future use.

(11) Appendix D contains the "raw" data collected during this study. This data forms the basis from which the historical profiles were derived.

(12) Appendix E contains systems descriptions for the software systems studied.

(13) Appendix F contains all trip reports filed as a result of this study.

II. Summary

SECTION II

SUMMARY

This section is separated into two parts. The first part is an executive summary describing the evolution of software supportability risk assessment within the Air Force Operational Test and Evaluation Center (AFOTEC). The second part is a technical summary of the results from the current task to provide AFOTEC personnel with data to support the methodology to assess software supportability risk.

2.1 EXECUTIVE SUMMARY

2.1.1 Concept Development.

a. Since 1982, AFOTEC has been analyzing the problem of how to assess the risk to the Air Force of supporting software acquired for weapon systems. A concept for computer resources risk assessment during operational test and evaluation was proposed in 1983 (reference 8.20). Several issues evolved from this proposal. First, the assessed risk should reflect software supportability impact upon the system at a level appropriate for AFOTEC reporting requirements. Second, supportability is a concern for both the user and the supporter. Any defined risk of software supportability should reflect some aspect of user risk and supporter risk. Third, current AFOTEC methods of evaluating software supportability should be integrated into the risk assessment method. Also, the risk assessment method should be adaptable to include other AFOTEC concerns such as software maturity and software reliability.

b. This initial concept proposal provided AFOTEC with justification to study the feasibility of developing and implementing a risk assessment methodology for software supportability (RAMSS). The approach for this study (references 8.1, 8.2, 8.3) included:

(1) Literature review and assemblage of a data base of relevant tools, techniques and methods

(2) Analysis of relevant tools, techniques, and methods for feasibility of application to AFOTEC's needs

(3) Development of a framework for assessing software supportability risk along with a preliminary set of risk measures.

c. The primary conclusion from this feasibility study was that a RAMSS could be developed based upon the framework derived as part of the study. However, there were still several technical issues which needed to be resolved. Of these issues, the major one concerned the need to establish a baseline against which to measure risk. Since risk is defined (for this study) as "the potential for realization of unwanted, negative consequences of an event," it is necessary to have a baseline of software support activities in order to tell when a consequence may be negative. This baseline, called an historical maintenance profile, reflects how software support resources are being used to perform the software support activities. Given this information, the framework recommended by the feasibility study could be used to compute measures of risk and incorporate the issues proposed in 1983.

2.1.2 <u>Methodology Requirements (Inputs)</u>. Figure 2-1 illustrates interfaces with the proposed risk assessment methodology for software supportability (RAMSS). The inputs consist of:

(1) The historical profile of software maintenance activity

(2) A user/supporter agreement on planned software maintenance changes and support resource requirements for the software system being evaluated

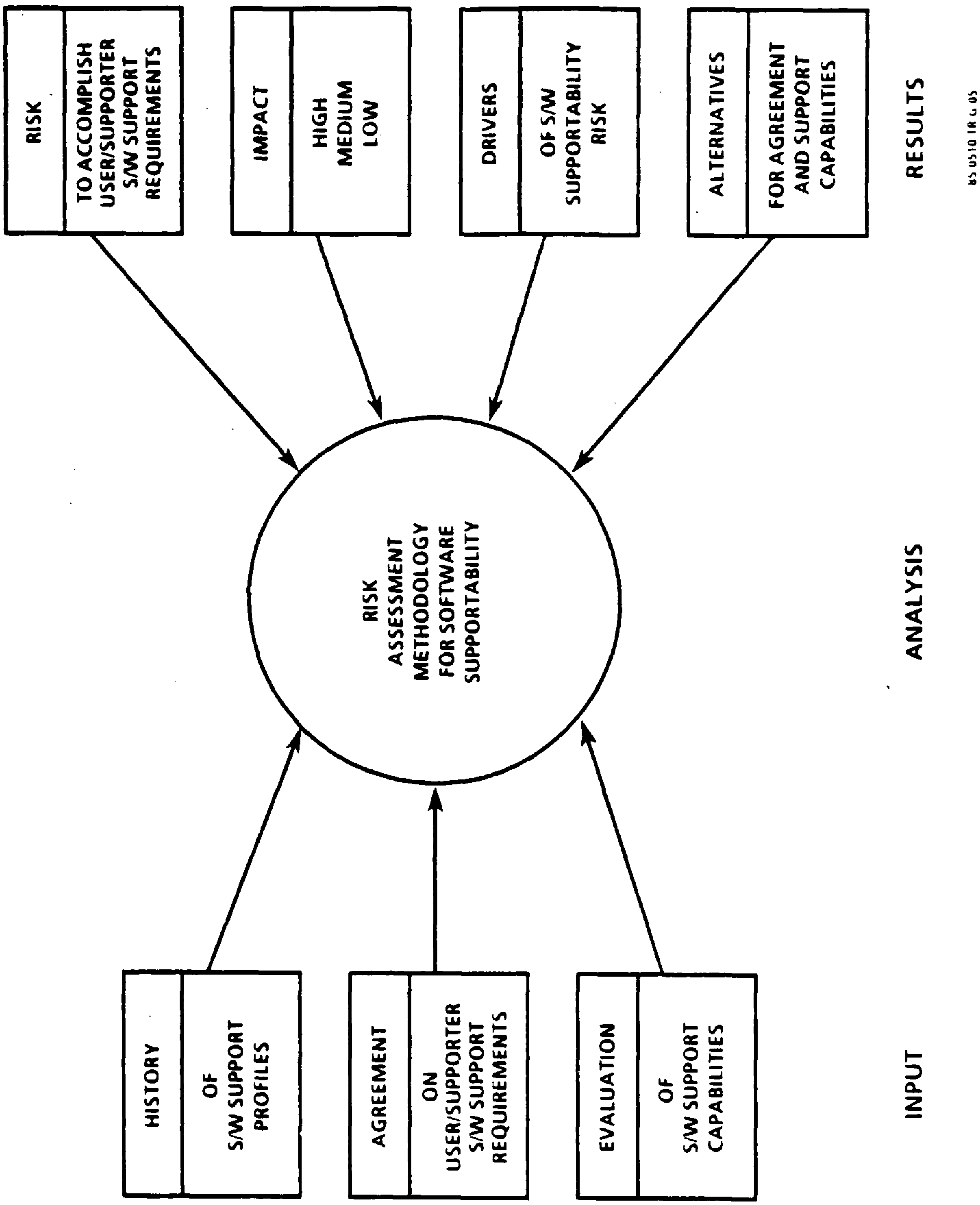

Figure 2-1. High Level View of Risk Assessment Methodology for Software Supportability

(3) An evaluation of software support capabilities using current AFOTEC methods.

2.1.3 Methodology Analysis. The RAMSS inputs are combined and analyzed to compute measures of risk for the system being evaluated.

2.1.4 Methodology Benefits (Results).

a. The major results of the RAMSS are also illustrated in figure 2-1. These results include:

(1) The risk measure which quantifies the probability of the user/support agreement not being accomplished with current software support capabilities

(2) The capability to identify the impact of the total system risk as high, medium, or low

(3) The identification of the drivers of the software supportability risk

(4) The projection of alternative choices for risk reduction (for instance, by improving certain aspects of current or projected software support capabilities).

b. With this information, the decision maker can assess the effect of software supportability upon system suitability and effectiveness. In addition, detailed data are available to help answer specific questions such as why particular areas of software supportability are drivers and how the measured risk can be reduced to an acceptable level.

2.1.5 Conclusion. The main recommendation from the current study is that the proposed risk assessment methodology for software/supportability be applied in a closely controlled manner to an actual

software system operational test and evaluation effort. This is necessary in order to validate the methodology and establish procedures that will allow AFOTEC personnel to effectively apply the methodology in the operational test and evaluation of future systems.

2.2 TECHNICAL SUMMARY.

This part of the report summarizes the approach taken in conducting the study, describes the results of data analysis, presents a sample historical maintenance profile developed from the data, discusses the risk assessment methodology, and condenses the conclusions/recommendations.

2.2.1 Approach Overview.

a. The basic approach to gathering the software support activity data necessary to create historical maintenance profiles consisted of visiting selected locations that were performing the activities of interest. Early in the study it was recognized that a survey form should be developed to permit a standard method of collecting these data. AFOTEC and BDM personnel worked together to create the survey form and select the appropriate software support facilities to visit.

b. The format of the survey form created to collect the software support data consisted of preface statements followed by requests for three types of information: software background data, software assessment data, and desirable maintenance data. The preface statements introduced the purpose of the study, followed by definitions applicable to the survey. Software background data primarily identified and described characteristics of the software system being surveyed. The software assessment data were requested to determine the correlation between the software evaluation tools (which are capable of "measuring" the risk of supporting software) and a subjective assessment of risk by personnel who are currently

supporting the software of interest. The final data requested were the actual information that were used to build the risk profiles. Key elements included block release start and end dates, estimated and actual person effort, number and types of software changes implemented in the block release, and major problems.

c. Unlike the survey form, facility visit procedures were not formalized, but this report documents for future reference the methods employed. The methods are divided into pre-visit procedures, on-site visit procedures, and post-visit procedures. Pre-visit procedures primarily included initial telephone contact with the personnel targeted for the visit, as well as mailing the survey form in advance of the visit, along with a letter of confirmation from AFOTEC. Key pre-visit activities also included the identification of appropriate AFOTEC personnel to accompany the survey team, requests for early completion of the survey form, and the identification of senior software engineers for the software systems of interest. On-site visit procedures generally consisted of a management overview, followed by a briefing given to senior software engineers by AFOTEC personnel, and then a detailed presentation by BDM personnel on the software maintenance activity data being collected by this study. After obtaining the data and answering questions, a key item was to quality-check the data for completeness and consistency before ending the visit. Post-visit procedures consisted of organizing the information received and following through on open action items from the visit.

d. A total of seven installations were visited during this study. A list of these installations is shown in table 2-1. Trip reports from these visits are contained in appendix F of this report.

2.2.2 Results of Analysis. The goals of the data analysis effort have been to verify the data, reduce the data to a standard form,

Table 2-1.

Trip Schedule

SITE	DATE VISITED
NORAD	7-9 January 1985
Warner Robins ALC	28 January -1 February 1985
Sacramento ALC	24-26 February 1985
Castle AFB	27-28 February 1985
Ogden ALC	22-25 April 1985
*Oklahoma City ALC/Tinker AFB	13-16 May 1985
Langley AFB	21-25 July 1985

*The E-3A facilities at Tinker AFB were not associated with the Oklahoma City ALC

build a data base, assess data validity, report summary data information, build the historical maintenance profiles, and perform statistical data analysis. These activities were performed on the three types of data collected: background data, evaluation (assessment) data, and desirable maintenance activity data. Results of analysis are summarized below.

2.2.2.1 Background Data Analysis. Background data was collected more for descriptive completeness than for thorough statistical analysis. Some interesting results from this data include: (1) software systems studied varied from 1000 source lines of code to more than 2.8 million; (2) the number of personnel directly supporting the software varied from 1 to 84; (3) there is, on the average, one support person for every 24,000 lines of source code (with a data range from 300 lines to 273,000 lines per person). Analysis does not indicate direct correlation of background data collected with actual maintenance data collected. For example, there does not appear to be a direct correlation of software system size with the number of personnel supporting the system.

2.2.2.2 Evaluation Data Analysis.

a. Evaluation data was analyzed to determine relationships between the software evaluation tools used to "measure" the risk of software supportability and a subjective assessment of the risk by personnel now supporting the software.

b. Evaluation ratings were collected on 45 categories, of which 44 were measures of the system supportability characteristics which affect the risk of not being able to support a given system. The 45th evaluation rating was a direct rating of the overall risk as perceived by the evaluator. Factor analysis of the software supportability evaluation ratings showed that 37 of the rating categories (7 had insufficient data) could be combined into six factors interpreted as evaluating basic areas: support (configuration and maintenance) management, the product (software and documentation), personnel, organization, facilities, and support systems. These factors accounted for 79 percent of the total variance in the 37 rating categories; hence most of the information contained in the rating categories could be condensed into only 6 factors.

c. The six factors of software supportability were modeled to determine which factors have significant impact on the risk. Of the six factors, four were determined to be significant: support management, product, personnel, and support systems. Using these factors in the derived regression model was the best method of the three methods analyzed for computing risk from software supportability evaluation metrics.

d. The other two models for computing risk from software supportability metrics were another regression model and a simple linear function. For the regression model, the risk estimated by the survey site support personnel was regressed against the top level

software supportability metric. This model showed a reasonable fit to the plot of data points. This model did not account for as much variance as the factor regression model. As expected, the simple linear conversion of software supportability evaluation metric to risk using the formula:

$$\text{Risk} = 1 - \frac{\text{Evaluation Metric} - 1}{5}$$

provided the poorest fit to the data.

2.2.2.3 Maintenance Data Analysis.

a. Initial analysis of the software maintenance data involved determining what could be done with the data. This occurred as a result of insufficient knowledge at the beginning of this survey about the availability of certain desired critical data items. No system had all the information desired in an easily accessible form. Actual person effort per change or per block release was almost always unavailable. Nevertheless, intensive query of knowledgeable support personnel provided reasonably good block release data. The physical capability to record and retrieve the desired data exists, but there was simply no universal standard for what to collect or how to report it.

b. Analysis of the software release data focused upon creating the historical maintenance profiles with available person-months per change as a key parameter. Because this parameter was computed as a simple ratio for each release, and because the person-months are typically not known prior to completion of a release, it was desirable to analyze whether person-months per change was strongly correlated to some other known parameters. Linear regression analysis was conducted with independent variables being: number of source lines, percentage of correction requests, percentage of low

complexity changes, percentage of normal priority requests, percentage of high-level language, and average skill level of personnel. The results of the analysis showed no strong relationships. It is likely that the inconsistency and inaccuracy of some data affected these results.

2.2.3 Maintenance Profiles.

a. The actual historical maintenance profiles generated by the maintenance data collected in this study are contained in section V. The general form of the profiles, which plot the available person-months per change on the x-axis and the number of releases on the y-axis, is shown in figure 2-2. The profile represents the number (Y) of software releases accomplished with X "unit cost" (available person-months per software change required for that release). A software change is defined as a measureable change documented by a software change request or a similar item. Profiles

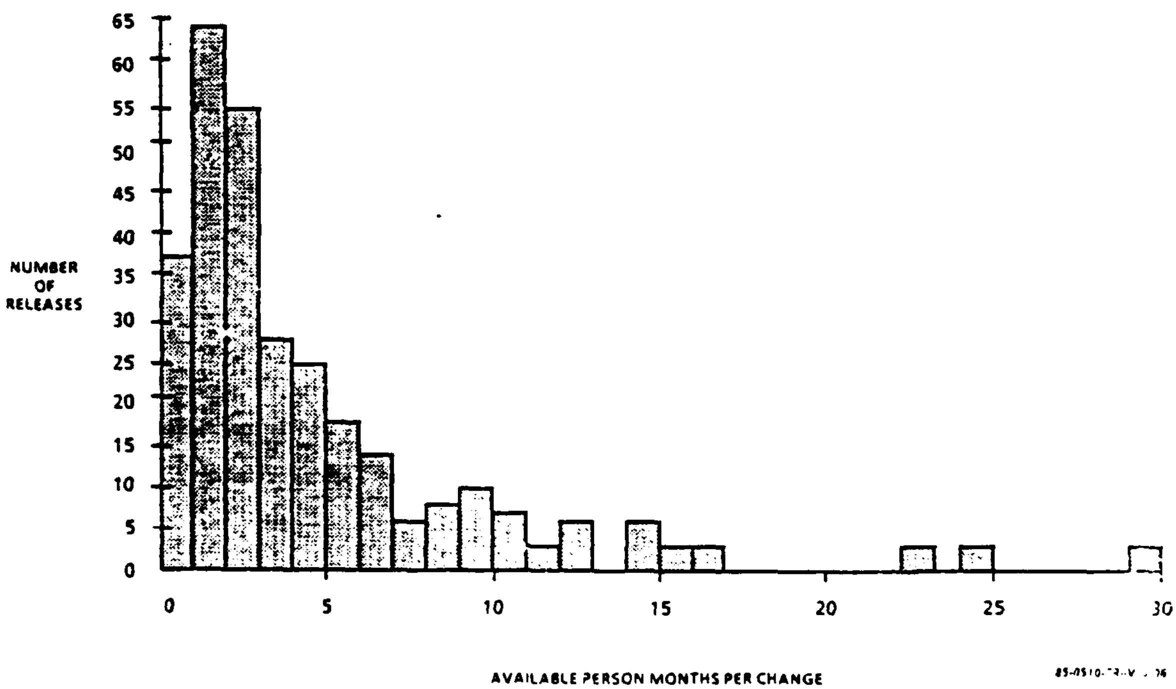

Figure 2-2. Historical Maintenance Profile Example

were also generated by software support site and software system type (e.g., operational flight program, communications-electronics). The profiles contained in this report thus form historical baselines against which the supportability risk of future systems can be assessed.

2.2.4 Methodology Review.

a. There are four basic phases involved in executing the risk assessment methodology for software supportability: planning, evaluation, analysis, and reporting. The primary function in the planning phase is to establish an appropriate baseline profile of expected maintenance actions. A second key function in the planning phase is to obtain user/supporter agreement on the "acceptable" support risk for the software system of interest. During the evaluation phase, the software system supportability is "measured" against this agreement using the software evaluation tools. The third phase, analysis, involves comparing the "acceptable" risk with the "measured" risk to examine differences and perform trade-off studies when the "measured" risk is greater than the "acceptable" risk. The final phase is the report to the decision maker on the results of the analysis which highlight risk measures, drivers, alternatives to reduce risk, and overall risk impact.

b. The primary refinement to the risk assessment methodology, as described in reference 8.3, is in the level of detail. The baseline software supportability profile of change requests still consists of 27 categories for the three software maintenance types, three levels of complexity, and three levels of priority in all combinations with each category having two values: time to complete request in a category, and number of requests in a category. However, practical limitations of the data collected during the survey resulted in a subset of the 27 categories being used, where time to complete is the release duration, and the nine categories of type, complexity and priority are used without any combinations.

c. Another instance, where a more detailed (rather than less detailed as in the baseline profile above) capability was derived from the analysis, is the software supportability risk computation. The simple linear conversion model should be replaced by the more accurate linear regression model, or the even better, but more computationally intensive, factor regression model.

d. Overall, the analysis supported the current risk assessment methodology reasonably well with the above relatively minor modifications.

2.2.5 Conclusions/Recommendations.

a. During this study, there were several observations about software support activities that merit comment and recommendations for additional action or study. These observations are summarized in table 2-2. The conclusions from the data analysis are summarized in table 2-3.

b. These observations and results support the primary objective of this study, which is to determine whether there is justification from the software support data to warrant further refinement and application of a risk assessment methodology. The authors of this report conclude that justification for refinement and application does exist. Analysis of the data indicates that the foundation for the methodology has been created and that the methodology is now ready for refinement and actual application via a pilot study. Refinement is still required in order to complete the software life cycle evaluation tool and adapt the other evaluation tools to conform to the RA methodology. The following ordered steps are recommended:

(1) Adapt the software maintainability tool to measure against the user/supporter baseline agreement

Table 2-2.

Summary of Problems

PROBLEM	SOLUTION
1. High personnel attrition rate	Requires further study
2. Inconsistent application of software configuration management system (CMS)	Set and enforce standard CMS procedures
3. Lack of agreement on definition of terms	Terms defined as part of standard CMS
4. Modifications to software take too long to reach the field	Study modification, testing, and release process to streamline
5. Systems support apportioned among multiple ALCs	Requires concept change for ALC operation
6. Contractors not transferring the software responsibility to support facilities	Need more information
7. System memory and processing constraints for embedded (OFP) software development	Technology enhancement and evolution of systems over time. Problem recognition for future systems.

Table 2-3.

Summary of Data Analysis Conclusions

ANALYSIS	CONCLUSIONS
1. Software Supportability Risk Computation	1a. The simple linear conversion model is not supported.
	1b. The linear regression model is supported with somewhat low confidence.
	1c. The factor regression model is supported with most confidence. The four driver factors are software product, software support management, software personnel, and software support systems.
	1d. The six significant factors derived for use in the factor regression model coincide with elements of the AFOTEC software supportability evaluation hierarchy.
2. Software System Release Data	2a. The person-months per change is not significantly correlated with number of source lines, proportion of correction requests, proportion of low complexity requests, proportion of normal priority requests, percentage of high-level language source, or average skill of support personnel.
	2b. The lack of any strong correlation in the results of 2a is attributed largely to the coarse nature of the available data.
3. Historical Maintenance Profiles	3a. There was not strong support for stratifying profile data by site.
	3b. There was some support for stratifying profile data by software system type, although the lack of data for some types hindered the overall conclusions.

(2) Adapt the software support facility evaluation tool (ASSET) to measure against the user/supporter baseline agreement

(3) Complete the top level software life cycle process evaluation metrics for risk assessment

(4) Apply the total software supportability risk assessment methodology to a current program. Evaluate results of application and complete technology transfer to AFOTEC personnel

(5) Continue the collection of software system release data. A recommended data collection form and procedure for temporary use is presented in section 3.6

(6) Develop procedures to update the historical maintenance profiles and analysis results from the newly collected software system release data

(7) Continue to evolve the software supportability risk computation regression analysis results. Use the factor regression model, the linear regression model, and the simple linear model in that order of preference.

(8) Continue to analyze potential relationships between person-months per change and other system level variables such as percentage of low complexity change requests.

III. Overview of Approach

SECTION III

OVERVIEW OF APPROACH

3.1 INTRODUCTION.

a. From the very beginning of this study, it was recognized that a standardized, repeatable method was necessary to collect the software maintenance activity data. Meetings were held with AFOTEC personnel shortly after initiation of this subtask to gain agreement on the types of data to be collected and the form/format that would be used to collect the data. Whereas the general format of the survey form which resulted from these meetings remained constant during the study, several changes occurred during the course of the study as greater insight was obtained about the utility of the form and the types of data desired. This report will not discuss the detailed history of the evaluation of the form from its first to its current (seventh) draft, however, discussion of the pitfalls of some of the earlier versions will be discussed in section 3.3 of this report.

b. In conjunction with AFOTEC, procedures were also created to set up and perform the facility visits. These procedures were modified as the study progressed and more was learned about what approaches worked best.

c. It would be wrong to assume that using the survey form or facility visit procedures discussed in this report will guarantee complete success in collecting desired information. The uniqueness of the facilities and systems visited meant that constant minor adjustments were being made to respond to each situation. This state of affairs will likely continue until a more uniform system for collecting and reporting software maintenance activity data is enforced Air Force- or DoD-wide.

d. As an initial effort, recommendations are made in section 3.6 for a temporary data collection form to be used by all support sites. This data would be necessary for the upgrade and evolution of the data collected during this study in support of the software supportability risk evaluation.

3.2 ASSUMPTIONS OF SOFTWARE MAINTENANCE ACTIVITY.

a. The "view" of the software support activity evolved somewhat during the process of integrating the collected data in order to achieve consistency and commonality across software systems. The resulting assumptions of the activity which most systems follow to some extent have these major properties:

(1) Responsibility. Software support has been assumed either formally through a Program Management Responsibility Transfer (PMRT), or informally such as after Initial Operational Capability (IOC). Changes are being processed to an operational system within a formal configuration management process.

(2) Block Release. The software maintenance process is based on production of a scheduled or unscheduled block release. Each change request is a (reasonably) formal item which is tracked under configuration management status accounting. Releases may overlap and share resources. The term "percentage of resources dedicated to a release" is used to balance the available resources which account for the productivity of a given release.

(3) Change Request. A software change request can be classified by type, complexity, and priority. The type is correction, enhancement, or conversion. The complexity is low, medium, or high. The priority is normal, urgent,

or emergency. Software change requests are prioritized and grouped into a change block or release. The change block is processed as a software development effort, including analysis, requirements, design, code and unit test, integration and operational test, and formal delivery and installation. The emphasis on each phase will depend upon the change block and the operational system.

(4) Data. Major software maintenance parameters of interest include:

a) Block release start date, engineering end date, field date

b) Number of personnel assigned to block release and percentage of the time these personnel are dedicated to the release

c) Skill level of personnel assigned to block release

d) Estimated level of resource requirements (personnel and systems) for block release at start date

e) Actual level of resources consumed (personnel and systems) for block release at engineering end date

f) For each change request in the block release, the type, complexity, priority, estimated and actual resource requirements, configuration control dates

g) The total number of change requests which were carried over for consideration in a future block release.

(5) Personnel. Resources include organic (military/civilian government) and/or contractor personnel. Personnel are those directly associated with the given software system in management, technical, support, or contractor capacity. Resources may be shared across software systems. The term "percentage of resources dedicated to the software system" is used to balance the available resources which account for the productivity of a given release.

b. A software system may not satisfy the above assumptions in all aspects. The majority of the software systems for which data was obtained did satisfy many of these assumptions. Problems, exceptions, workarounds, and so forth will be discussed, as appropriate, throughout this report.

3.3 SURVEY FORMAT.

a. The Data Survey Form (Draft 7, dated 29 April 1985) is presented in appendix C of this report. The basic sections of this form will be discussed in the following paragraphs.

b. The types of data collected using the form can be divided into three categories: (1) background data on each software system surveyed; (2) a high-level, subjective assessment of the adequacy of the software support being provided for each major software system; and (3) actual software maintenance data for each major software system. Hence the data collection form is also divided into these categories. The data collected in each category will be discussed in some detail.

3.3.1 Survey Form - Preface Information.

a. Information was presented at the front of the form as an introduction to the purpose of the requested software support data,

and three pages of definitions were attached. This format was selected because it appeared advantageous to mail a copy of the survey form to the individuals from whom desired information was anticipated prior to the facility visit being conducted. The intent was to minimize the time spent during the facility visits introducing the purpose of the survey, thereby concentrating on obtaining all applicable data. This approach had some measure of success, because early drafts of the survey form did not have an introduction. It was discovered that most recipients of the survey form at that time waited until the facility visit was being conducted before researching the requested information. During later facility visits, where the preface information was provided with the survey form, there was a greater tendency for individuals to have some of the desired information ready when the facility visit began.

b. It was also evident from early versions of the survey form that there was potential for disagreement or misunderstanding about the meaning of some of the terms used in the form itself. Therefore, to prevent such occurrences, and to provide an increased potential for obtaining consistent responses among facility visits, definitions of key terms were included in the preface to the survey. These definitions have been used consistently throughout the risk assessment study, including the feasibility study for the RAMSS.

3.3.2 Survey Form - Software Background Data.

a. The background data requested consists of two basic types: (1) identification data (system name, software system name, software system type) and (2) description data, which was necessary to better understand the characteristics of the software support being provided.

b. Not all of the description data gathered was intended to be useful in developing risk profiles of maintenance activities.

However, given the opportunity to collect this information, it was decided the data might be used for future additional analysis. For instance, the size of the software system (# CSCIs, # Modules, # Source lines) and the languages (and percent use) information were not planned to be part of the risk assessment methodology. Analysis (see section IV) indicates this information was not significant for the data reported. However, given enough data more accurate than was collected, the significance of this information might change. It might be interesting, given that one knows the size and language of a system being evaluated by the RAMSS, to assess the risk against systems whose size and language are close to that of the target system.

c. The description data which are basic to the risk profile development are the number of personnel currently supporting the software system and a measure of the amount of time such personnel are dedicated to supporting the system. *This information must* be obtained as accurately as possible because the model depends upon a measure of the historical productivity for the software system support. Other information on personnel skill levels could be very important, however analysis did not seem to provide any consistent results as to how personnel skill levels affect maintenance effort. Still, with more accurate data than was collected, such information might be an indication of why some productivity measures are different.

d. The remainder of the data collected under background information primarily indicates characteristics of software support activities that represent problems, or special circumstances which might explain why data collected on some systems are significantly different from what was expected (for example, a temporary freeze on enhancement, or a high attrition rate of experienced personnel).

3.3.3 Survey Form - Software Assessment Data.

a. The purpose for this part of the survey form was to collect information which allowed a high level correlation between the AFOTEC supportability evaluation tools (which are intended to "measure" the risk of supporting software) and a subjective assessment of risk by personnel who are currently supporting the software. This correlation was intended to provide information about how close, across systems, the proposed evaluation tools come to measuring perceived risk. This information was influential in determining the relationship between numeric evaluation scores obtained by applying the evaluation tools and subsequent conversion to a risk metric. For example, the initial attempt to relate a numeric evaluation score of software system supportability (on a 1 to 6 scale, where 1 is worst and 6 is best) to a risk assessment score (on a scale of 0 to 1, where 0 is absolute certainty of being able to support the software system and 1 is absolute certainty of not being able to support the software system) might indicate that a linear relationship exists. In other words if M = overall support score (1-6), and R = risk (0-1), then linearly:

$$R = 1 - \frac{M-1}{5} .$$

Analyzing (see section IV) the software assessment data collected in this section of the survey form indicates a different (nonlinear) relationship is more likely to be valid.

b. The survey form requests ratings for the attributes used to measure software supportability at both delivery and current times. Delivery time means that time when the software system was turned over to the supporter for maintenance. This information was desired to indicate trends in the overall support of software following delivery. It could be used to pinpoint problem areas if the scores in various areas went from positive values at delivery time to negative values at the current time.

c. Several comments are appropriate about the evolution of this section of the form. The survey form originally requested an evaluation on a scale of 1 to 100 (worst to best) of the software support system's attributes as described by the tools used to measure the maintainability of the software system. Later in this study, the scale was changed from "1 to 100" to "-50 to +50," with a condition that "zero" not be chosen. This change was made because it seemed easier to associate a negative number with a negative (or inadequate) rating. Zero was eliminated as a choice because its absence forced raters to chose between whether the support attribute was either adequate or inadequate for the software support system. Also, this forced the raters to think harder about what a term meant and to get more information if not enough was present to make a decision. If the rater isn't sure what to put, zero may appear to be an easy out.

d. Other minor changes to this section of the survey form included: (1) an expansion of information in the software support environment section to obtain more data on the adequacy of software support systems, and (2) the addition of an overall evaluation (scale of -50 to +50) for the supportability of the entire system. This latter addition provides a three level correlation of assessment data. For example, an overall score of +45 would not correlate to sub-scores of negative values. Should this happen, it might indicate that the rater took something into account that the evaluation methodology does not measure. This information could be valuable for evaluation methodology enhancement.

3.3.4 Survey Form - Desirable Maintenance Data.

a. This section of the survey form lists the major data items which were desirable to be collected. It probably was the most changed portion of the original form. These changes occurred because initial attempts at collecting the data at the level of detail proposed in the RAMSS report (reference 8.3) were too time consuming.

The data proposed for collection in reference 8.3 included: for each software change or maintenance activity (such activity being documented by a software change request, software trouble report, software problem report, software maintenance request, or other traceable entity), the average time to complete each priority (emergency, urgent, or normal) activity (enhancement, conversion, or correction) with a high, medium or low complexity. More simply stated, the model required that information on each software maintenance activity be classified in one of 27 categories (3 priorities x 3 types x 3 complexity levels) and that the precise time to perform such activity be known.

b. Unfortunately, the information was not usually present in the facilities visited at the above level of detail. In particular, the information about the performance time for each maintenance activity was not being accurately recorded at the facilities. In addition, while it was usually possible to indicate how many total maintenance activities were emergency, urgent, or normal for each system, it was not usually possible for example, to break the number of emergency changes into high, medium, or low complexity.

c. The information requested has evolved into a more reasonable, and by experience more collectable, request for software maintenance activity by block release. A block release is a defined collection of maintenance activities which form an operational baseline for the system. Information was requested about each block release, such as specific software changes implemented, estimated person effort, actual person effort, engineering start and end dates, and times from engineering end date until release was fielded. Information on each change was still requested as before (put in one of 27 categories) because, were it available, much better evaluations of risk could be performed by being able to identify the drivers of risk at a lower level. Finally, additional data was requested about such items as the number of software change requests carried over from the previous

year, opened during the current year, and closed during the current year. This data was not generally available, but would provide information on the ability of the support facility to keep up with the support requests and should correlate with other risk assessment variables.

3.4 FACILITY VISIT PROCEDURES.

While there were no formal facility visit procedures established at the beginning of this study, a discussion of the general procedures followed will hopefully be of benefit to future study efforts. The procedures can be divided into pre-visit, on-site visit, and post-visit activities. Each of these activities has proven to be necessary for a successful data collection effort.

3.4.1 Pre-Visit Procedures.

a. Pre-visit procedures and activities were primarily accomplished by AFOTEC. They basically consisted of telephoning the facilities targeted for visits several weeks in advance of the visit to confirm what software systems were being supported and who would be the primary points of contact. AFOTEC personnel also coordinated an appropriate time for the visit, and briefly explained over the telephone the purpose of the visit. AFOTEC designated appropriate government personnel to accompany BDM personnel on the visits. In addition, AFOTEC sent a letter to each office contacted (see figure 3-1 for a sample letter). The letter verified the visit, its purpose, and contained a copy of the survey form as an attachment. When possible, BDM and AFOTEC personnel reviewed any available documentation on the systems to be visited prior to the trip.

b. There are three key items which should be noted about pre-visit activities:

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE OPERATIONAL TEST AND EVALUATION CENTER
KIRTLAND AIR FORCE BASE, NEW MEXICO 87117-5000

REPLY TO ATTN OF: LG

SUBJECT: Request for Visit and Site Survey

TO: (Two or Three Letter Office, as appropriate)

1. Reference telecons between Lt Col Smith and Capt Tomlin on 2 July 85, and, between Mr Jones and Capt Tomlin, and Maj Hunter and Capt Tomlin on 5 July 85.

2. We would like to visit your facilities for two days beginning 23 July 85 to collect a variety of data described in the attached Site Survey Form. The survey is an important part of our efforts to develop a methodology to assess the risk of supporting system software. This assessment is to be used within the initial operational test environment. Your valuable assistance and cooperation will provide a significant contribution to this effort.

3. We have initially developed a methodology of assessing software support risk. However, the methodology depends on developing profiles of software support activities. The attached site survey has been designed to capture the data needed to build the profiles of activity and the background information necessary to describe historical and current experiences. We have found it essential to key in on the senior software engineer (or equivalent) for each system as our starting point and source of the majority of information. We have also found copies of the CRISP and O/S CMP for each system most helpful. We are supplying the survey in advance so that each senior software engineer may be aware of the type of information we are seeking, determine if other personnel should be interviewed, and prepare data sources as appropriate.

4. This entire effort to develop a risk assessment of software supportability has been with the aid of the BDM Corporation. Two of their personnel and one from our Software Evaluation Division will make the visit. Upon your confirmation, we will send a message with names and security clearences the week prior to our visit.

5. Questions and comments should be addressed to Capt Eric Tomlin, HQ AFOTEC/LG5T, AV 246-1381, or, Maj Gary Horlbeck, HQ AFOTEC/LG5T, AV 246-1254.

FOR THE COMMANDER

(Signature Block)

1 Atch
Site Survey Package

Figure 3-1. Sample Letter

(1) The success of a facility visit was highly dependent upon AFOTEC's designation of a "key" government (AFOTEC) employee to accompany BDM personnel on the visit. This "key" person has usually been previously assigned to the facility or its vicinity, and/or was knowledgeable of the personnel who were visited. This designation occurred in all visits except one.

(2) The earlier letters sent to prospective facilities did not request that survey form information be prepared in advance. Later versions of the letters requested that, when possible, the survey form information should be available at the time the visit was performed. This proved to be beneficial in some instances. Most individuals, however, waited until the facility visit was performed before attempting to complete the survey form.

(3) A final key item was the early identification of the senior software engineer (or equivalent) on each system visited. The knowledge of this individual, who almost always had been working with the system for some time and was therefore very familiar with the history of the system as well as its current status, has proven to be extremely important to obtaining the necessary data in a timely manner.

3.4.2 <u>On-Site Visit Procedures</u>.

a. As with the pre-visit procedures, it was learned that some methods of approach worked better than others when the facility visit was actually being performed. Because of the time constraint involved in the visits, there was a natural tendency to want to get right to the software engineers to start collecting information. However, in all cases some time was spent with upper level management

explaining the purpose of the visit. This was a necessary step that should not be avoided because it enhanced cooperation during the visit.

b. The next logical step was to get together with as many of the software engineers as possible to explain the purpose of the visit and discuss the information desired. It was not possible to perform this step for a large group because the software engineers were spread out in various locations at the facilities. For the most part, separate meetings with each system or subsystem software engineers were performed. The methods which appeared to provide the most timely information included:

(1) AFOTEC personnel gave a short introduction to the briefing purpose.

(2) BDM personnel presented about a 30- to 45-minute discussion of the methodology and data desired.

(3) At the conclusion of the meeting, decisions were made about when to return to the software engineer to collect the data and answer questions.

c. A key piece of advice: make every attempt to collect all appropriate data, documents, evaluation forms, or other important information <u>before</u> concluding the visit. There are several instances, when information which was promised has not been received.

d. Other areas to be aware of during the data collection process include:

(1) *Instruct the software engineers on the following items regarding the software assessment data form in the survey.* <u>All</u> blanks are to be completed on this form

(only a few will have non-applicable items under software support environment). Do not enter a zero. If program management responsibility for the system was never transferred (many systems were developed organically), or "At Delivery" has no meaning, then only complete the "Current" column.

(2) Check over the completed form for completeness and consistency. Several individuals were confused about the assignment of supportability risk.

(3) Ensure that all data received is understood with regard to its meaning and content. Look for completeness and consistency in the software maintenance data. The time to clear up problems is <u>during</u> the visit, not afterward.

3.4.3 <u>Post-Visit Procedures</u>. BDM personnel have compiled notebooks from each visit. These notebooks contain a copy of the trip reports, and an indexed filing of all documents, notes, organization charts, software evaluation forms, and maintenance data collected during the facility visit. These notebooks will be maintained by BDM personnel.

3.5 FACILITIES VISITED AND SYSTEMS EXAMINED.

a. A total of six data collection visits were performed during this study. The facilities and dates of the trips are summarized in table 3-1.

b. Summaries of each trip may be found in appendix F of this document.

Table 3-1.

Trip Schedule

SITE	DATE VISITED
NORAD	7-9 January 1985
Warner Robins ALC	28 January - 1 February 1985
Sacramento ALC	24-26 February 1985
Castle AFB	27-28 February 1985
Ogden ALC	22-25 April 1985
*Oklahoma City ALC/Tinker AFB	13-16 May 1985
Langley AFB	21-25 July 1985

*The E-3A facilities at Tinker AFB were not associated with the Oklahoma City ALC.

c. Table 3-2 lists, by facility visited, the systems/subsystems examined to date by this study. The following abbreviations apply:

(1) NORAD — North American Aerospace Defense Command, Cheyenne Mountain Complex, Colorado Springs, Colorado

(2) WR-ALC — Warner Robins ALC, Robins AFB, Georgia

(3) SM-ALC — Sacramento ALC, McClellan AFB, California

(4) CASTLE AFB — Castle AFB, California

(5) OO-ALC — Ogden ALC, Hill AFB, Utah

(6) OC-ALC — Oklahoma City ALC, Tinker AFB, Oklahoma

(7) TINKER — E-3A Facility, Tinker AFB, Oklahoma

(8) LANGLEY — Langley AFB, Virginia

Table 3-2.

Software Systems Examined

SITE	SYSTEM	SOFTWARE SYSTEM
NORAD	CSS	CSS
NORAD	MDS	MDS
NORAD	MEBU	MEBU
NORAD	NCS	NCS
NORAD	SSC	SSC
WR-ALC	ALR-46	ALR-46
WR-ALC	ALR-69	ALR-69
WR-ALC	AN/ALQ-131	AGEOP
WR-ALC	AN/ALQ-131	BTG
WR-ALC	AN/ALQ-131	OFP
WR-ALC	ALQ-131	UUT
WR-ALC	APR-38	APR-38
WR-ALC	B-52 EVS ATE	ASQ-151
WR-ALC	E-3A AVIONICS ATE	AN/GSM-285(B)
WR-ALC	E-3A AVIONICS ATE	AN/GSM-285(W)
WR-ALC	F-15	CC
WR-ALC	F-15	RADAR
WR-ALC	F-15 AVIONICS ATE	ADTS,AIS
WR-ALC	JTIDS	ASIT/OCP
WR-ALC	JTIDS	E-3A AWACS/OCP
WR-ALC	JTIDS	SP/USER
WR-ALC	JTIDS	SYS EXERCISER
WR-ALC	PAVE TACK	AISF
WR-ALC	PAVE TACK	OFP
SM-ALC	F-111D	WEAP-NAV COMPUTER
SM-ALC	F-111F	WEAP-NAV COMPUTER
SM-ALC	FB-111A	WEAP-NAV COMPUTER
CASTLE AFB	A T-4	A T-4 SIMULATOR
CASTLE AFB	B-52	CPT
CASTLE AFB	B-52	WST
CASTLE AFB	KC-135	WST
OO-ALC	F-16	FCC
OO-ALC	F-16	HUD
OO-ALC	F-16	OFT
OO-ALC	F-16	FCR
OO-ALC	F-16	SMS
OO-ALC	F-4	MDTS
OO-ALC	F-4E	AN/ARN-101
OO-ALC	F-4G	AN/ARN-101
OO-ALC	F-4G	LRU-1/ACM
OO-ALC	MINUTEMAN	WING II/2015
OO-ALC	MINUTEMAN	WING VI/HS-29
OO-ALC	MINUTEMAN	WINGS/HS-28

Table 3-2

Software Systems Examined (Continued)

OO-ALC	MINUTEMAN II	SSAS/CAPS
OO-ALC	MINUTEMAN II	WING V/HEG/RATS
OO-ALC	MINUTEMAN II	WING VI/HEG/RATS
OO-ALC	RF-4	CAN/ARN-101
OC-ALC	ALCM	LEVEL 1 TEST
OC-ALC	ALCM	LOADED PYLON TEST
OC-ALC	ALCM	OFP
OC-ALC	B-1B	CADC
OC-ALC	B-1B	CITS
OC-ALC	B-1B	EMUX
OC-ALC	B-1B	F/CGMS
OC-ALC	B-1B	INS
OC-ALC	B-1B	ORS
OC-ALC	B-52	BNST
OC-ALC	B-52	FTSS
OC-ALC	B-52	MC-1 EXEC
OO-ALC	B-52	MC-2 EXEC
OC-ALC	E-3	INS
OC-ALC	E-3A	OMEGA
OC-ALC	E-3A	SMCP
OC-ALC	E-3A	SRCP
OC-ALC	E-3A	SRGSCP
OC-ALC	GLCM	DPS
OC-ALC	GLCM	M-DTD
OC-ALC	GLCM	MPT
OC-ALC	GLCM	OFP
OC-ALC	GLCM	WCS
OC-ALC	SRAM	OFP
TINKER	E-3A	AOCP
TINKER	E-3A	UTIL SUPP S/W
LANGLEY	JTIDS	ASIT/TPOCP
LANGLEY	STRTS	STRTS
LANGLEY	TACS	CAFMS
LANGLEY	TIPI	DC/SR
LANGLEY	TIPI	II/MARRES/TEREC
LANGLEY	407L	HUGHES UTIL
LANGLEY	407L	IBM UTIL
LANGLEY	407L	IORP/IMPP

3.6 RECOMMENDED SITE DATA COLLECTION FORM.

On the basis of the experience and analyses from this study, it is recommended that data be collected for each software system release at each software support site for each software system being supported. This subsection includes a definition of the data items to be collected, and recommended temporary procedures for getting the data integrated into the AFOTEC Software Maintenance Profiles. Tools to automate the data integration would need to be constructed.

3.6.1 Data Items. The recommended data items to be collected for each software system release are shown in figure 3-2. Each of these data items is briefly discussed in the following paragraphs. Although many other data items are of interest (such as estimated versus actual values), the combination of the analysis results (section IV) and practical concern for site personnel time constraints limited the data collection effort to the specified items. Experience from the numerous site visits indicates that the recommended data items are available during the software release effort and would not be time consuming to collect and record on a compact form such as shown in figure 3-2.

3.6.1.1 SITE. The SITE is the named location which provides the organic management and/or technical support for the subject software system.

Example: Ogden Air Logistics Center (OO-ALC)

3.6.1.2 SYSTEM. The SYSTEM is the collective set of hardware/software of which the subject software system is a part.

Example: F-16

3.6.1.3 SOFTWARE SYSTEM. The SOFTWARE SYSTEM is the name of the collective software package (documentation, source, object, command

COMPUTER SOFTWARE RELEASE DATA RECORD			DATE
1. SITE	2. SYSTEM	3. SOFTWARE SYSTEM	4. SOFTWARE SYSTEM TYPE

5. SIZE (K LINES)	6. LANGUAGE	NAME	% SOURCE LINES	HOL.(Y/N)
		a.		
		b.		
		c.		
		d.		

7. PERSONNEL		# ORGANIC	% DEDICATED	# CONTRACTOR	% DEDICATED
(LOWEST)	SKILL LEVEL 1.				
	SKILL LEVEL 2.				
	SKILL LEVEL 3.				
	SKILL LEVEL 4.				
(HIGHEST)	SKILL LEVEL 5.				

8. RELEASE ID/VERSION	9. RELEASE START DATE	10. RELEASE ENGINEERING COMPLETION DATE	11. RELEASE FIELD DATE

12. RELEASE CHANGE DATA (USE ADDITIONAL ATTACHMENTS AS NECESSARY)

CHANGE REQUEST ID	OPEN DATE	CLOSE DATE	ACTUAL PERSON MONTHS	TYPE (C,E,V)	COMPLEXITY (L,M,H)	PRIORITY (N,U,E)

AFOTEC FORM XXXX
SEP 85

85-0510-TR W III 01

Figure 3-2. Recommended Software Release Data

language) for which change release data is being reported. The software may be (but need not be) at the CSCI level.

Example: Stores Management System (SMS)

3.6.1.4 SOFTWARE SYSTEM TYPE. The SOFTWARE SYSTEM TYPE is one of the following categories:

OFP - Operational Flight Program
C-E - Communication-Electronics
EW - Electronic Warfare
ATD - Aircrew Training Device/Operational Flight Trainer
ATE - Automatic Test Equipment
SIM - Simulation
SUP - Support (system or application)

Example: OFP

3.6.1.5 SIZE. The SIZE is the number of computer language source lines in thousands (K) for the subject software system. Percentage of comments should be estimated.

Example: 153K (25% Comments)

3.6.1.6 LANGUAGE. The LANGUAGE is a list of computer programming and command/test languages in which the subject software system source is written. Language includes usual programming languages such as FORTRAN, JOVIAL, COBOL, Ada, Assembly, etc. The percentage of each language's source lines should be specified along with an indication (Y=yes, N=no) whether the language is a High Order Language (HOL) or not.

Example: 8080 Assembly 100% N

3.6.1.7 PERSONNEL.

a. The PERSONNEL is the count of all persons assigned the direct support responsibility for the subject software system.

Functionally, these personnel represent managers, maintainers, programmers, analysts, configuration/quality assurance personnel, testers, etc. The personnel counts should be separated into organic (civilian and Air Force) and contractor, and also by approximate skill level.

Skill level 1: the least experienced and knowledgeable personnel.
Skill level 5: the most experienced and knowledgeable personnel.
Skill level 2, 3, 4: the ranges between the levels 1 and 5.

Typically, the junior personnel with little experience or those personnel without the necessary programming/analysis skills would fall into the levels 1 or 2. Those personnel who have much experience with the subject software system, and generally whose capabilities are considered critical to the support of the subject software system fall into the levels 4 or 5.

b. The % DEDICATED is the percentage of time which the support personnel are dedicated to the subject software system release as opposed to some other releases or other software systems. If the personnel were working only on the subject software release, then this percentage would be 100.

Example: As an extended example, if nine F-16 SMS organic support personnel were distributed so that 5 (level 2) were 100% dedicated, 3 (level 3) were 75% dedicated, and 1 (level 4) was 50% dedicated, then the data would be listed as follows:

	# Organic	% Dedicated	#Contractor	%Dedicated
Skill level 1	0	0		
Skill level 2	5	100		
Skill level 3	3	75		
Skill level 4	1	50		
Skill level 5	0	0		

3.6.1.8 RELEASE ID/VERSION. The RELEASE ID/VERSION is a unique identifier for the subject software release being reported.

Example: SF1

3.6.1.9 RELEASE START DATE. The RELEASE START DATE is that date when major analysis activity related to the subject software release begins for which software support personnel are required.

Example: 01/01/83

3.6.1.10 RELEASE ENGINEERING COMPLETION DATE. The RELEASE ENGINEERING COMPLETION DATE is that date when the software engineering part of the release is complete. The activities completed for the project block release include design, code, unit test, integration test, and operational test and evaluation. Time for "kit" proofing, prom burning, modification of technical orders, and other such activities which typically occur between the engineering completion and actual field implementation is *not* included. A typical release cycle might be 18 months with the first 12 months for software engineering and the last 6 months for technical order preparation and field distribution.

Example: 06/01/83

3.6.1.11 RELEASE FIELD DATE. The RELEASE FIELD DATE is that date when the subject software release is officially distributed to the field for operational use. See paragraph 3.6.1.10 for some further discussion. If the release was never fielded, specify NOT FIELDED.

Example: 09/01/83

3.6.1.12 CHANGE DATA. The CHANGE DATA is classification and effort information on each software change request (correction of deficiency, enhancement due to addition or deletion of a capability, or conversion change due to an external system requirement modification) in the subject software release. Individual fields are described below, and an example is shown in figure 3-3.

EXAMPLE OF CHANGE DATA

CHANGE REQUEST ID	OPEN DATE	CLOSE DATE	ACTUAL PERSON MONTHS	TYPE (C,E,V)	COMPLEXITY (L,M,H)	PRIORITY (N,U,E)
S-155-002	11/11/82	5/1/83	6	E	H	N
S-155-003	11/1/82	4/1/83	7	E	H	N
S-155-005	11/1/82	2/1/83	.5	E	L	N
S-155-006	12/1/82	2/1/83	.5	E	L	N
S-155-007	1/1/83	3/1/83	1	E	M	N
S-155-011	1/1/83	3/1/83	2	E	M	N
S-155-022	2/1/83	4/1/83	.5	E	L	N
S-155-024	2/1/83	5/1/83	1	E	M	N
S-155-018	1/1/83	6/1/83	.5	E	L	N
S-155-019	1/1/83	4/1/83	1	E	M	N
S-155-020	1/1/83	2/1/83	1	E	L	N
S-155-021	1/1/83	2/1/83	1	E	L	N
S-155-022	1/1/83	3/1/83	.5	E	L	N
S-155-024	1/1/83	4/1/83	2	C	M	N
S-155-027	1/1/83	3/1/83	.5	E	L	N
S-155-029	1/1/83	6/1/83	5	E	H	N
S-155-034	1/1/83	5/1/83	1	E	L	N
S-155-038	1/1/83	5/1/83	1	E	M	N
S-155-042	1/1/83	3/1/83	1	E	M	N
S-155-049	1/1/83	3/1/83	1	E	L	N
S-155-055	1/1/83	2/1/83	.5	C	L	N
S-155-056	1/1/83	2/1/83	.5	C	L	N

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Figure 3-3. Example of Change Data

(1) Change Request ID. Unique identifier for the change request.

(2) Configuration Management Open Date. Date change request was opened by configuration management.

(3) Configuration Management Close Date. Date change request was closed by configuration management.

(4) Actual Person Months. Actual person months to complete the change request

(5) Change Request Type. Correction (C), Enhancement (E), Conversion (V).

(6) Change Request Complexity. Low (L), Medium (M), High (H)

(7) Change Request Priority. Normal (N), Urgent (U), Emergency (E).

See the glossary for further definition of the change request type, complexity, and priority.

3.6.2 Data Collection Procedure.

a. It is recommended that all Air Force software support sites (AFLCs, MAJCOM support facilities) collect the minimal data items described in paragraph 3.6.1 for each official software release of each mission critical software system being supported. Data collection would begin at any point in the software life cycle when a sustained software support effort with uniquely identified software releases was being accomplished under direct control of the site management. The actual support personnel could be organic, contractor or some combination. Typically this would occur at some

time after Initial Operational Capability and no later than Program Management Responsibility Transfer.

b. The specific data collection form could be something like that illustrated in figure 3-2 as a temporary measure, but would probably need to evolve into an official Air Force form. There might be a requirement to integrate this information (format and content) with the requirements of related Air Force regulations and practices such as AFM 66-1, Maintenance Management (Reference 8.13), or AFR 800-18, Air Force Reliability and Maintainability Program (reference 8.14).

c. Of prime importance is the integration of the collected data with the current data described in this report. AFOTEC personnel need to have a straightforward approach to obtaining and merging new release data into the release data base (see section on BASE III data bases) and updating the maintenance profiles based upon the updated data. In addition, any statistical analysis based upon changed data items such as predicted person months per change would need to be updated. As a part of the data collection procedure, it is recommended that AFOTEC develop the appropriate procedures and tools to facilitate this regular update process.

d. A top level view of the data collection procedure and AFOTEC update of the maintenance profiles is illustrated in figure 3-4.

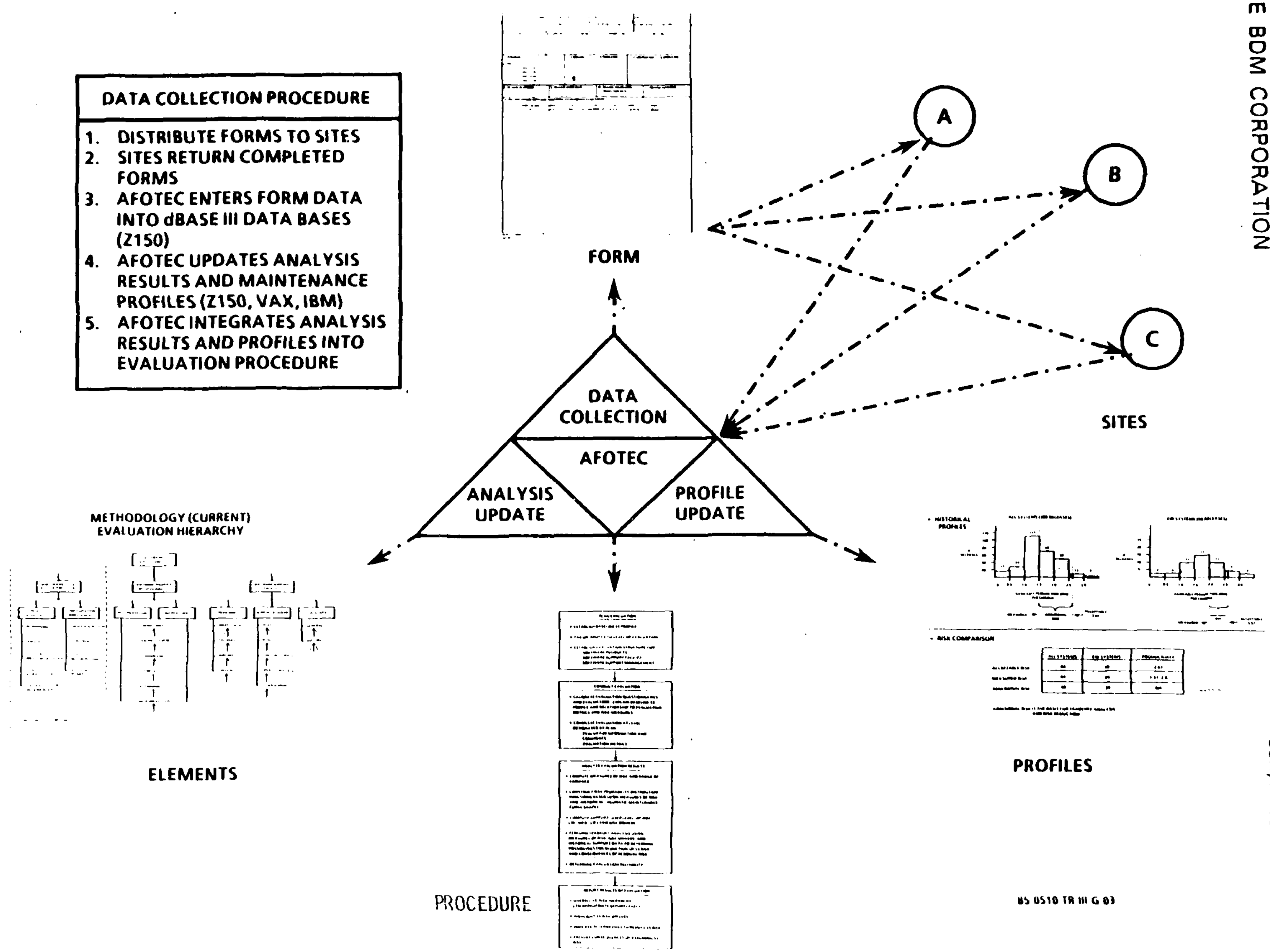

Figure 3-4. Maintenance Data Collection Process and Profile Update

IV. Results of Analysis

SECTION IV
RESULTS OF ANALYSIS

4.1 INTRODUCTION.

a. This section reports on a variety of analyses conducted on the software supportability and maintenance data collected during this effort. With the exception of histograms of available person-time, which are presented as Maintenance Profiles in Section V, all analytical results are presented in this section.

b. The goals of the analysis conducted during this study include:

(1) Verify that consistent data on system background, evaluation support and risk metrics, and system maintenance activity has been collected

(2) Reduce data to usable form, consistent across systems

(3) Enter data into a dBASE III format on an IBM-compatible microcomputer for ease of analysis, reporting, and entry to the BMDP statistical analysis package. (The BMDP package used was resident on a VAX 11/780 computer.)

(4) Determine accuracy of data and general confidence in data

(5) Produce summary reports of raw and computed data

(6) Build profiles of software maintenance activity data

(7) Conduct statistical analyses of data

(8) Derive conclusions concerning impact upon the current Risk Assessment Methodology for Software Supportability.

c. A summary of the status of these goals is presented in table 4-1.

4.2 OVERVIEW OF ANALYSIS ENVIRONMENT.

This section contains a brief description of the environment in which the data collected during this study effort was organized, analyzed, and reported.

4.2.1 Hardware/Software System. The hardware and software used to support the data analysis are illustrated in figure 4-1. The primary data storage, organization and summary analysis were done using the dBASE III data base management software (reference 8.15) on an IBM PC with two floppy disks and a dot matrix printer. A SmarTerm 220 communication terminal emulator (reference 8.16) was used to provide the capability to transfer data files from the IBM PC to a VAX 11/780. The bulk of the statistical analyses was conducted on the VAX using the BMDP statistical software package (reference 8.17).

4.2.2 dBASE III Analysis Data Files.

a. All of the data are organized onto three disks using dBASE III on an IBM PC. Disk 1 mainly contains the data taken off the evaluation form (see appendix C). Disk 2 contains the maintenance data collected on software block releases. Disk 3 contains system identification information.

b. dBASE III is a relational model for data base management systems. It is used here to (1) structure data bases, (2) facilitate data entry and management, (3) produce reports, and (4) obtain preliminary analysis results.

Table 4-1.

Summary of Analysis Results and Status

GOAL	STATUS	CONFIDENCE (DATA/PROCESS)
Verify Data	Complete.	Low/Medium
Reduce Data	Complete.	Medium/Medium
Build Data Base	Complete.	Medium/High
Analyze Data Validity	Complete.	Low/Medium
Report Data	Complete. Data reports (appendix D) and analysis reports (section IV) have been generated.	Medium/High
Build Profiles	Basic required profiles (all systems, by site, by software type) have been generated.	Medium/High
Analyze Data	Analysis on profiles, correlation of support metric to risk, and correlation of categories to person time is complete. Factor and regression analyses are complete.	Medium/High
Determine Methodology Impact	BASELINE SUPPORT PROFILE 1. Basic profile data (type, complexity, priority) has not changed. Availability of conversion data was limited by data recording technique, not by actual functional use. Priority data did not seem to be universally important in the mission critical categories of emergency, urgent, normal. Prioritizing the change requests did seem to be universal, however. 2. The historical profile has changed substantially in form. Focus is upon individual block release and the available person time per change. As more accurate data is available, actual/estimated person time and personnel skill levels can be used. As more accurate data is available, change type, complexity, and priority can be useful.	Medium/Medium

Table 4-1.

Summary of Analysis Results and Status (Concluded)

GOAL	STATUS	CONFIDENCE (DATA/PROCESS)
	3. Data is not easily available, but could be.	
	4. Data is not consistent, but could be much better.	
	5. Data collected needs to be centrally located in a data base for historical baseline.	
	6. Derivation of a baseline support profile will not be difficult; agreement on such a baseline by user/supporter will be most difficult.	
	EVALUATION PROCEDURE	Medium/Medium
	1. Calibration will be very important.	
	2. Product evaluation will not be significantly different.	
	3. Environment evaluation will be impacted by integrating the baseline support agreement.	
	4. Life cycle evaluation has been mentioned by several evaluators as very important. There seemed to be more interest in this part than expected, and very little resistance or difficulty in completing the survey form. AFOTEC needs to implement this evaluation.	
	5. Procedure for continuing maintenance data collection has been recommended.	
	EVALUATION METRIC TO RISK CONVERSION	Medium/High
	1. Linear Conversion Model. Analysis of data indicates a poor fit.	
	2. Logistic Transform Model. Analysis of data indicates a better fit than the linear model.	
	3. Factor Regression Model. Analysis of data indicates which factors are drivers for determining risk.	

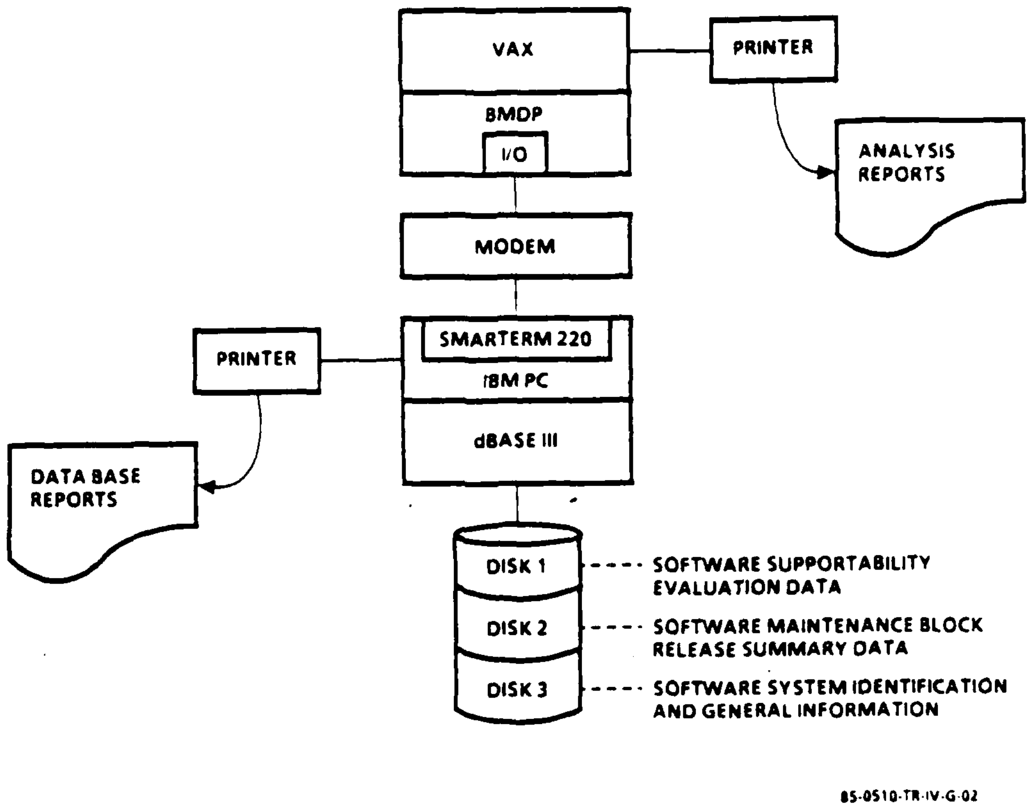

Figure 4-1. Hardware/Software Analysis Support System

c. The data files are transmitted via modem using a SmarTerm 220 disk in the IBM PC to a VAX for analysis using the BMDP statistical software.

4.2.2.1 Disk 1: Software Supportability Evaluation Data. This disk contains 56 files. A one line general description for each file is contained in the file FILEDESC.DBF indexed by the file FILEDESC.NDX. The four primary data bases are: SYSINFO, EVALG, EVALD, and EVALC. They are described in the following four sections.

4.2.2.1.1 SYSINFO: Software System Information. This data base is an identical copy from Disk 3. See the Disk 3 description for further information.

4.2.2.1.2 EVALG: General Descriptive Information. This data base has 29 items of information primarily concerned with the background data collected from part 1.2 of the site survey form (see appendix C). EVALG is ordered by an evaluation identification number (EVALID) using the index file EVALIDG.NDX. EVALG is linked to the SYSINFO data base by software system identification number (SWSYSID) to access software system information.

4.2.2.1.3 EVALD: Evaluation Data On Systems At Delivery Time. This data base has 48 items of evaluation data on systems "at delivery" from part 2 of the site survey form (see appendix C). EVALD is also ordered by evaluation identification number (EVALID), using the index file EVALIDD.NDX. EVALD is linked to the SYSINFO data base by software system identification number (SWSYSID) to access software system information. It can also link to the EVALG data base by EVALID to access general evaluation information.

4.2.2.1.4 EVALC: Evaluation Data on Systems at Current Time. This data base, identical in structure to EVALD, has 48 items of evaluation data on "current" systems from part 2 of the site survey form

(see appendix C). EVALC is ordered by evaluation identification number (EVALID) using the index file EVALIDC.NDX. It is linked to the SYSINFO data base by software system identification number (SWSYSID) to access software system information. It also can link to the EVALG data base by EVALID to access general evaluation information.

4.2.2.2 Disk 2: Software Maintenance Block Release Summary Data. This disk contains 21 files. A one line general description for each file is contained in the file FILEDESC.DBF indexed by the file FILEDESC.NDX. The two primary data bases are SYSINFO and RLS_SMRY. They are described in the following two sections.

4.2.2.2.1 SYSINFO: Software System Information. This data base is an identical copy from Disk 3. See the Disk 3 description for further information.

4.2.2.2.2 RLS_SMRY: Software System Block Release Summary Data. This data base has 21 items of information on software maintenance block releases, corresponding to data described in part 3 of the site survey form (see appendix C). RLS_SMRY is ordered by software system identification number (SWSYSID) and release identification number (RLSID) using index file RLS_SMRY.NDX. It is linked to the SYSINFO data base by SWSYSID to access software system information.

4.2.2.3 Disk 3: System Identification Information. This disk contains 19 files. A one line general description for each file is contained in the file FILEDESC.DBF indexed by the file FILEDESC.NDX. The two primary data bases are: SYSINFO and SWSYSDES. They are described in the following two sections.

4.2.2.3.1 SYSINFO: Software System Information. This data base contains 10 items of software system identification data collected in part 1.1 of the site survey form (see appendix C). SYSINFO is ordered by a software system identification number (SWSYSID) using

index file SWSYSID.NDX. The data items KLINES and PCHILEV are the system averages for variables of the same name in the general evaluation data base (EVALG) on disk 1. These items, along with NSITE, NSWTYPE, and AVGSKILL, are included in this data base because they are needed on a system basis for analysis. The SYSINFO data bases on both Disks 1 and 2 are identical to this data base.

4.2.2.3.2 SWSYSDES: Software System Description. This data base holds a brief description of each software system for which data was collected during this study effort. SWSYSDES is linked to the SYSINFO data base by software system identification number (SWSYSID) to access software system information. It is ordered by software system identification number (SWSYSID) using the index file SWSYSDES.NDX.

4.2.3 BMDP Statistical Analysis Software.

a. The BMDP computer programs are designed to aid data analysis by providing methods ranging from simple data display and description to advanced statistical techniques. Data are usually analyzed by an iterative "examine and modify" series of steps. First the data are examined for unreasonable values, graphically and numerically. If unreasonable values are found they are checked and, if possible, corrected. An analysis is then performed. This analysis may identify other inconsistent observations or indicate that further analyses are needed. The BMDP programs are designed to handle all steps in an analysis, from the simple to the sophisticated.

b. The BMDP programs are organized so the problem to be analyzed, the variables to be used in the analysis, and the layout of the data are specified in a uniform manner for all programs. This permits different analyses of the same data with only minor changes in the instructions.

c. See reference 8.17 for further information on the BMDP software.

4.3 BACKGROUND DATA ANALYSIS.

At every site visited, survey forms like the one shown in Appendix C were distributed to knowledgeable software maintenance personnel for completion. For virtually all of the software systems encountered, at least one survey form was completed. Reported in this section are analysis results for the background data collected in section 1 of the survey forms (see page C-6).

4.3.1 Summary Results. Listed below are summary results for the major areas covered under background data for all the systems surveyed. A complete (except for individual evaluator names) list of background data is presented in appendix D. A summary of the background data results by the major areas is presented in table 4-2.

4.3.1.1 Software System Types. There were 7 types of software systems for which data was collected: OFP, C-E, EW, ATD, ATE, SIM, SUP. Only the OFP, C-E, EW, and SUP types had substantial amounts of maintenance data. Analysis results stratified by software system type are presented in other parts of section 4 and in section 5.

4.3.1.2 Software System Size. The size of the software systems in thousands (K) of source lines being supported ranged from 1K to 2,800K. The average size (total source lines divided by number of software systems reporting data) is 181K. The average number of source lines supported by one person is 23K, with a range of 0.3K to 200K.

4.3.1.3 Language Usage. The predominant source language for software systems in the survey is assembly. A wide variety of assembly

Table 4-2. Summary Background Data

AREA	DESCRIPTIONS OF RESULTS
1. SOFTWARE SYSTEM TYPES	# OFP SOFTWARE SYSTEMS - 32 % OFP SOFTWARE SYSTEM RELEASES - 24 # C-E SOFTWARE SYSTEMS - 13 % C-E SOFTWARE SYSTEM RELEASES - 51 # EW SOFTWARE SYSTEMS - 5 % EW SOFTWARE SYSTEM RELEASES - 7 # ATD SOFTWARE SYSTEMS - 7 % ATD SOFTWARE SYSTEM RELEASES - 3 # ATE SOFTWARE SYSTEMS - 7 % ATE SOFTWARE SYSTEM RELEASES - 5 # SIM SOFTWARE SYSTEMS - 6 % SIM SOFTWARE SYSTEM RELEASES - 2 # SUP SOFTWARE SYSTEMS - 11 % SUP SOFTWARE SYSTEM RELEASES - 8
2. SOFTWARE SYSTEM SIZE	LARGEST SOURCE LINES - 2800K SMALLEST SOURCE LINES - 1K AVERAGE SOURCE LINES - 181K
3. LANGUAGE USAGE	PRIMARILY ASSEMBLY
4. DEVELOPMENT	FIVE OR SIX CONTRACTORS HAVE DEVELOPED MOST OF THE SYSTEMS
5. LIFE CYCLE EVENTS (IMPACT SOFTWARE SUPPORT)	MAJOR CONVERSION EFFORTS.
6. PERSONNEL	LARGEST SUPPORT GROUP SIZE - 84 SMALLEST SUPPORT GROUP SIZE - 1 AVERAGE SOURCE LINES SUPPORTED PER PERSON - 23 K RANGE (.3K .. 200K)
7. SUPPORT SYSTEMS	WIDE VARIETY OF SUPPORT SYSTEM TYPE, CAPABILITY AND % DEDICATED FOR SOFTWARE SYSTEM SUPPORT. AVAILABILITY OF SUPPORT SYSTEMS IS A PROBLEM.
8. PROBLEMS	LACK OF ENOUGH QUALIFIED PERSONNEL ATTRITION OF QUALIFIED PERSONNEL QUALITY OF DOCUMENTATION OVERHEAD MANAGEMENT AND EXTERNAL TIME DEMANDS CONFIGURATION MANAGEMENT INTER-ORGANIZATIONAL INTERFACES

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and high order languages (FORTRAN, JOVIAL, COBOL, PL/I, data base, etc.) were in use. It appears that the more recent systems (e.g., F-16) have a higher percentage of high order language source.

4.3.1.4 Development. The development background data included development period, development contractor(s), and approximate level of effort. This data was not generally known except for the development contractor. Five or six contractors tended to be the predominant developers.

4.3.1.5 Life Cycle Events. Life cycle events which had major impact upon the software support varied from political concerns to technology concerns. One event that consistently had a major impact was a major conversion effort due to application hardware modifications. Attrition of key personnel and changeover in support contractors were other major events. The contractor change impact was bad or good depending upon the circumstances. Official government PMRT was also considered to be a major event, usually with positive impact.

4.3.1.6 Personnel. The number of personnel supporting a software system varied from one to 84. The average number of source lines (k) supported by one person was 23K with a range from 0.3K to 200K.

4.3.1.7 Support Systems. Background data on support systems included a list of (or reference to a list of) support hardware/software and an indication of the percentage of time the support systems were available for use. Although the data was pretty limited, it was apparent that a wide variety of hardware and software support was being utilized with a part of the support systems (especially integrated laboratory equipment) application specific. Frequently support systems were being used by several groups including users and training personnel. Quite often availability of support systems was considered a problem.

4.3.1.8 Problems. Problems most frequently mentioned were lack of qualified personnel, inability to keep qualified personnel, quality of documentation, overhead management and external time demands, configuration management, and inter-organization interfaces.

4.4 EVALUATION DATA ANALYSIS.

a. The evaluation data consists of a high level, subjective rating of each software system's support aspects and an estimate of the software system's overall supportability risk (see appendices C and D). Evaluation data were obtained relative to two different points in time: delivery of the software for support, and current time. In the case where delivery was essentially the same as current time, the two evaluations were the same. One evaluation per system was completed by a lead support person for the system (for a few systems, several evaluations were done by several evaluators).

b. There were several problems with the evaluation data which contribute to the generally low confidence in the absolute accuracy of this data. These problems are summarized below:

(1) Missing Data. Some of the evaluators for the systems surveyed early in the study left blanks. This missing data is very difficult to integrate.

(2) Focus of Risk. The early evaluations did not focus on the specific concept that the risk is based upon completion of a block release within the resources (e.g., time, systems, and personnel) assigned at the start of the block change cycle. Most of this problem was due to the evolution of the survey process itself. Generally this means that even if the supportability metrics indicated good scores, the risk was contradictorily estimated to be high (e.g., 1.0). In later surveys, the evaluators were

more carefully instructed as to the meaning of the risk and consequently the estimations of risk were more closely related to the supportability metrics.

(3) Terminology Consistency. As with all subjective evaluations it is necessary to carefully explain terminology and provide for calibration, review, and frequent delphi-like corrections. These evaluations had very little benefit of these techniques. The anticipated review of the data by the evaluators in the context of this report and in comparison to other systems should provide some improvement in the evaluation data consistency, accuracy, and confidence in the results.

c. A general observation based upon the evaluation data and the survey process is that an evaluation can be conducted relative to a support baseline. However, a good explanation of the terminology, process, and desired focus is essential during the calibration phase. Whenever this was done during the survey effort, the evaluation data seemed to be more consistent and within the bounds of what the methodology would predict (e.g., high support metrics associated with a low risk estimate). It appears that the software product evaluations will not be much affected by the nature of the support baseline, while the software support facility evaluation and the software life cycle management evaluation will be more directly affected. It is not understood how sensitive each of the evaluations would be to changes in the baseline profile. It is doubtful that any of the data collected in the survey would allow for any such conclusions. This sensitivity would be a good analysis issue to resolve during a pilot study where the methodology, complete with evaluations, is applied in a more consistent and controlled manner.

d. Evaluation ratings of 45 aspects of software system supportability were requested from survey respondents (evaluators) in

section 2 of the survey form (see pages C-7 and C-8). Evaluation ratings were collected on the software systems as they were at delivery and as they were in their current forms at the times the survey forms were administered. Since the current system evaluation data is of more immediate interest, and since the "at delivery" evaluation data is generally less reliable (because ratings were generally not collected at or soon after delivery, but were based on corporate memory of the system status at delivery some time in the past), the analyses of this section treat exclusively the ratings of current systems. Because these analyses examine the internal relationships among the supportability aspects rated, and the relationships should not differ essentially between delivered and current systems, it is anticipated that similar results would be obtained if these analyses were to be conducted on the ratings of systems at delivery.

e. Of the 45 evaluation ratings provided for on the survey form, the first 44 attempt to measure aspects of system supportability that are supposed to affect the risk of not being able to support a given system. The last evaluation rating is a direct rating of that risk as it is perceived by the evaluator. It is the goal of this section to explore and compare methods for converting supportability ratings into a risk measure.

4.4.1 Risk Versus General Software Supportability Rating. The general software supportability rating (labelled as 2.4.1 in the survey form) was intended to measure the general supportability of the software system. In this context, it was expected that the evaluator would in some fashion mentally integrate the ratings assigned to all the lower level aspects of supportability to arrive at a general supportability rating. Of course, it is also possible that the evaluator will integrate into the general supportability rating aspects of supportability which are not captured in the list of lower level aspects covered by the survey form. Ideally, the

evaluator's risk rating should closely, in an inverse manner, reflect the general supportability rating; that is, if general supportability is rated high, risk should be rated low, and vice versa. This section examines the relationship between general supportability rating and risk rating and means of converting general supportability rating to risk.

4.4.1.1 A Simple Linear Conversion Function. One way to convert general supportability rating to risk, though simple, is immediately obvious. It is via the linear function

$$R = 1 - (G + 50) / 100,$$

where

R = risk, and

G = general supportability rating.

This method is illustrated in figure 4-2 where actual data points collected from the site survey form are plotted. The horizontal axis of figure 4-2 is general supportability rating (labelled ASUPPORT), and the vertical axis is risk (labelled ARISK). The numerals in the plot indicate the number of data points occurring at a location (there is a total of 88 data points available from the set of survey forms). The diagonal straight line in the plot represents the linear function given above. It is evident from the plot that this straight line does not reflect the curved nature of the data, so that while the line does seem to fit the data at the upper left and lower right corners of the plot, it clearly does not fit well the data between the two corners. An alternative conversion function is needed.

4.4.1.2 A Linear Regression Approach.

a. There are numerous ways to arrive at a curvilinear function representing the relationship between risk, R, and general supportability rating, G. One way would be to fit directly a curvilinear

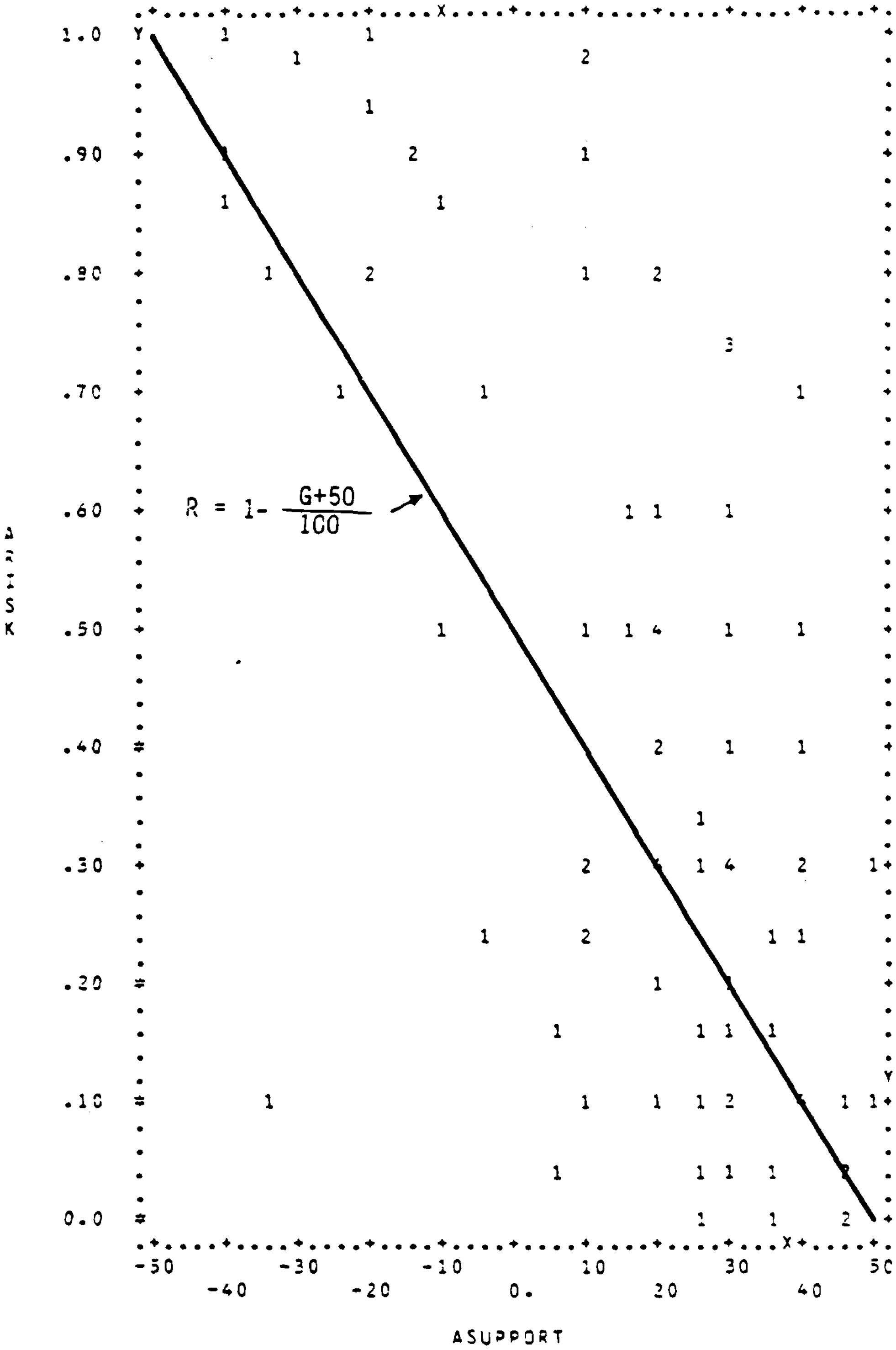


Figure 4-2. Risk Data and Simple Linear Conversion Function

function, $R = f(G)$, involving a polynomial, say. A difficulty of this approach is that it is not clear what form $f(G)$ should take, and interpretation may not be easy if $f(G)$ becomes very complex. Another approach is to fit a function $h(G)$ to some transformation, T, of R, so that the relationship becomes $T(R) = h(G)$. In certain cases, the function $T(R) = H(G)$ may be much simpler and more readily interpretable than the function $R = f(G)$. The approach employing a transformation of risk is used in the regression analysis below.

b. Note that risk values may not fall below zero, nor exceed one. These constraints should also be obeyed by any functional forms used to represent or predict risk. For example, a risk of 1.1 predicted by a function for a general supportability rating of -45 would be inadmissible. A transformation of risk that ensures these constraints will be met is the logistic transformation,

$$T(R) = \ln (R / (1 - R)).$$

With R taking values between zero and one, T(R) will take values between minus infinity and plus infinity. To see that the transformation meets the constraints, note that in the inverse transformation

$$T^{-1} (T(R)) = R = 1 / (1 + \exp (-T(R)),$$

when T(R) tends toward minus infinity, R will tend to zero. As T(R) goes to plus infinity, R will go to one. For T(R) equal to zero, R will equal one-half.

c. Since T(R) is undefined for R equal to zero or one, and since R may, and in fact does, assume those values, it is necessary to modify T(R) so that it is defined for R equal to zero or one. Here, the values of R are simply scaled inward slightly from the interval

endpoints zero and one before T(R) is applied. The scaling function used is

$$R' = R\,(1 - a) + (a / 2),$$

where a is a small positive number. R' thus scales values between 0 and 1 to values between (a / 2) and 1 - (a / 2), and T(R') is defined for all values of R, including 0 and 1. The overall transformation of R, then, is

$$L(R) = T(R') = \ln \frac{R\,(1 - a) + (a / 2)}{1 - (R\,(1 - a) + (a / 2))} .$$

For this analysis, a value of a = .001 was arbitrarily chosen.

d. The data of figure 4-2 are portrayed in figure 4-3 with transformed risk values L(R) on the vertical axis (labelled LRISK). From the scatter of the data, it appears quite reasonable to use a straight line to represent the relationship between transformed risk (L) and general supportability rating (G). The straight line regression model to be used is

$$L = b_0 + b_1\,G + e,$$

where e is a random error variable and b_0 and b_1 are parameters to be estimated. Fitting the above model via least squares, the solid straight line in figure 4-3 is obtained, the equation for which is

$$L = .65011 - .06674\,G.$$

This equation accounts for $R^2 \doteq .35$, or 35 percent, of the variation of L values about their mean.

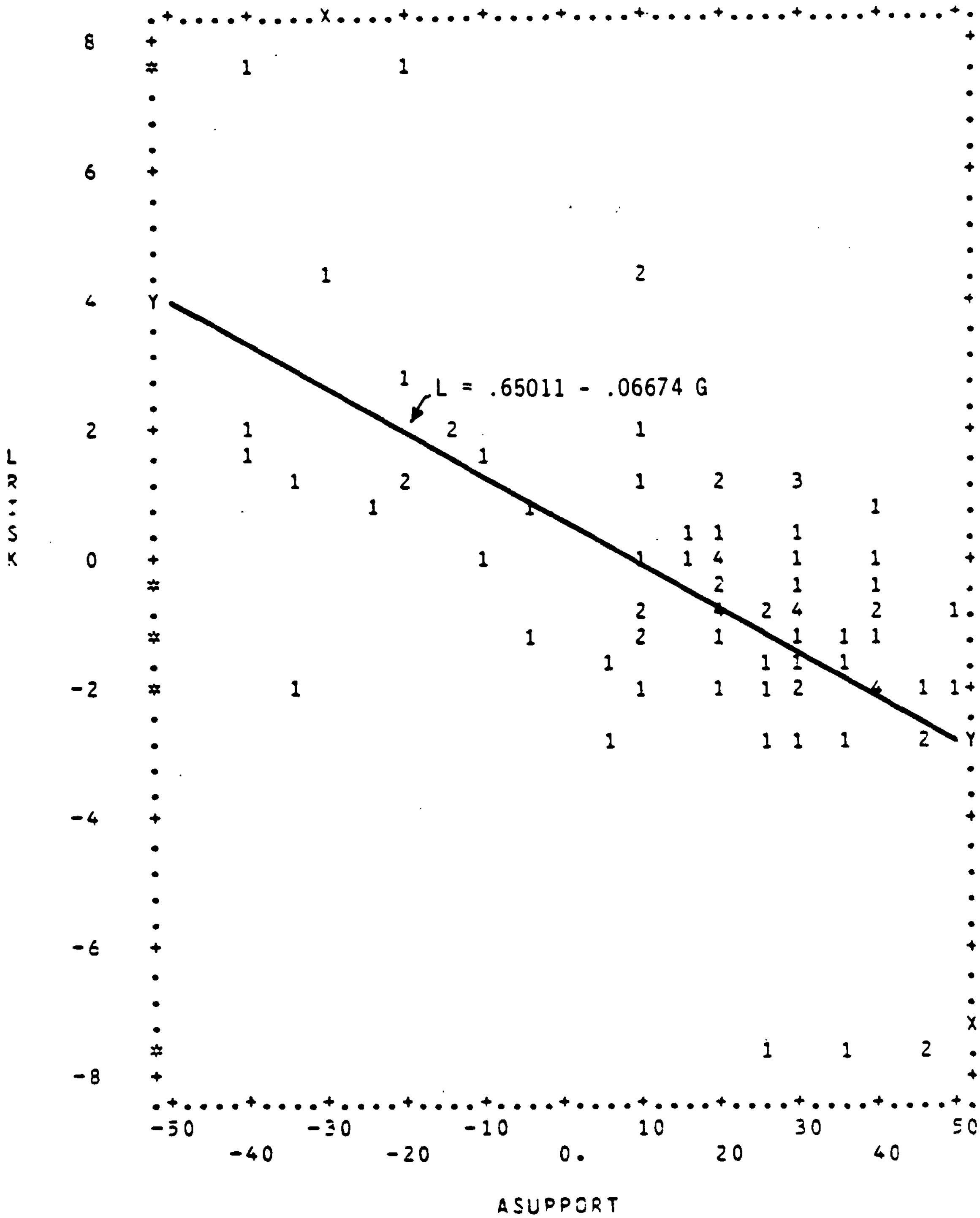


Figure 4-3. Transformed Risk Data and Fitted Regression Line

e. To provide a better view of what has been gained by this approach over that of previous section, both models are depicted on the risk scale in figure 4-4. The straight line is the linear conversion function of section 4.4.1.1, and the curved line is the model of this section detransformed to show risk values rather than transformed risk values. A transformed value L is detransformed to risk by the function

$$R = ((1 + \exp(-L))^{-1} - (a / 2)) / (1 - a).$$

The curved line better reflects the scatter of the data than does the straight line. Also noteworthy is the fact that neither model, when used for converting general supportability rating to risk, will yield risk values less than zero or greater than one.

f. The conversion of several general supportability metrics to risk using the linear model and the linear regression transform model is illustrated in table 4-3.

Table 4-3.

Conversion of General Supportability Metric to Risk

GENERAL SUPPORTABILITY METRIC 1..6	GENERAL SUPPORTABILITY METRIC -50..50	GENERAL SUPPORTABILITY RISK (LINEAR MODEL)	GENERAL SUPPORTABILITY RISK (REGRESSION TRANSFORM MODEL)
1.0	-50	1.00	0.98
1.5	-40	0.90	0.97
2.0	-30	0.80	0.93
2.5	-20	0.70	0.88
3.0	-10	0.60	0.79
3.5	0	0.50	0.66
4.0	10	0.40	0.50
4.5	20	0.30	0.34
5.0	30	0.20	0.21
5.5	40	0.10	0.12
6.0	50	0.00	0.06

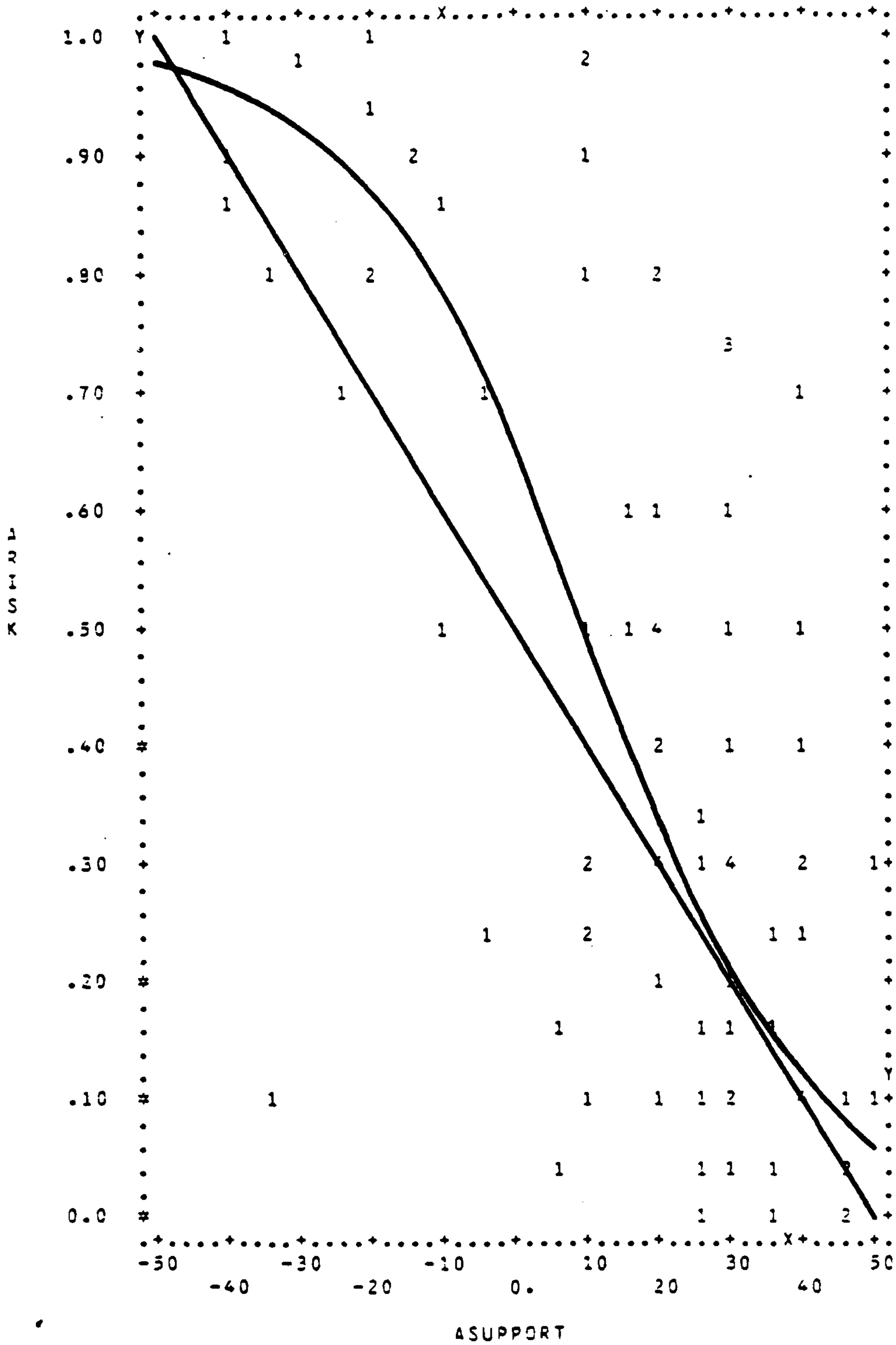


Figure 4-4. Comparison of Functions for Converting General Supportability Rating to Risk

4.4.2 Consolidation of the Supportability Ratings into a Few Supportability Factors.

a. Section 4.4.1 examined the conversion of general supportability rating to risk via two different functions. While either of those functions is relatively easy to use in obtaining a risk estimate from a general supportability rating, both rely solely on information available in the general supportability rating and ignore information contained in the other 43 supportability ratings (labelled as 2.1.1 through 2.3.3 in the survey form). Although the general supportability rating is intended to rate overall supportability, it relies on an evaluator's conscious or subconscious scheme for integrating all aspects of supportability and rating them with one number. Clearly, the importance attached to individual aspects of supportability in arriving at a general supportability rating will vary, perhaps considerably, from one evaluator to another in an unknown way. It is therefore desirable to develop a means of objectively (as opposed to subjectively) integrating the ratings of all the supportability aspects covered by the survey form. The sections below describe such an approach.

b. To set the stage for the next two sections, some initial results are presented here. Shown in figure 4-5 are correlation coefficients for pairs of rating variables that are related through the hierarchical structure of the survey form in appendix C. The variable names are straightforward abbreviations of the rating categories listed in the survey form. At the left side of figure 4-5 are the lowest level categories, at the right is the highest level category. In the variable name APDOCMOD, for example, "P" indicates the second-level category "product", "DOC" the third-level category "documentation" within "product", and "MOD" the fourth-level category "modularity" within "documentation" within "product". The variables in level 4 are listed in the same order as their respective categories in the survey form; thus, APDOCMOD reflects the category labelled 2.1.1.1 in the survey form.

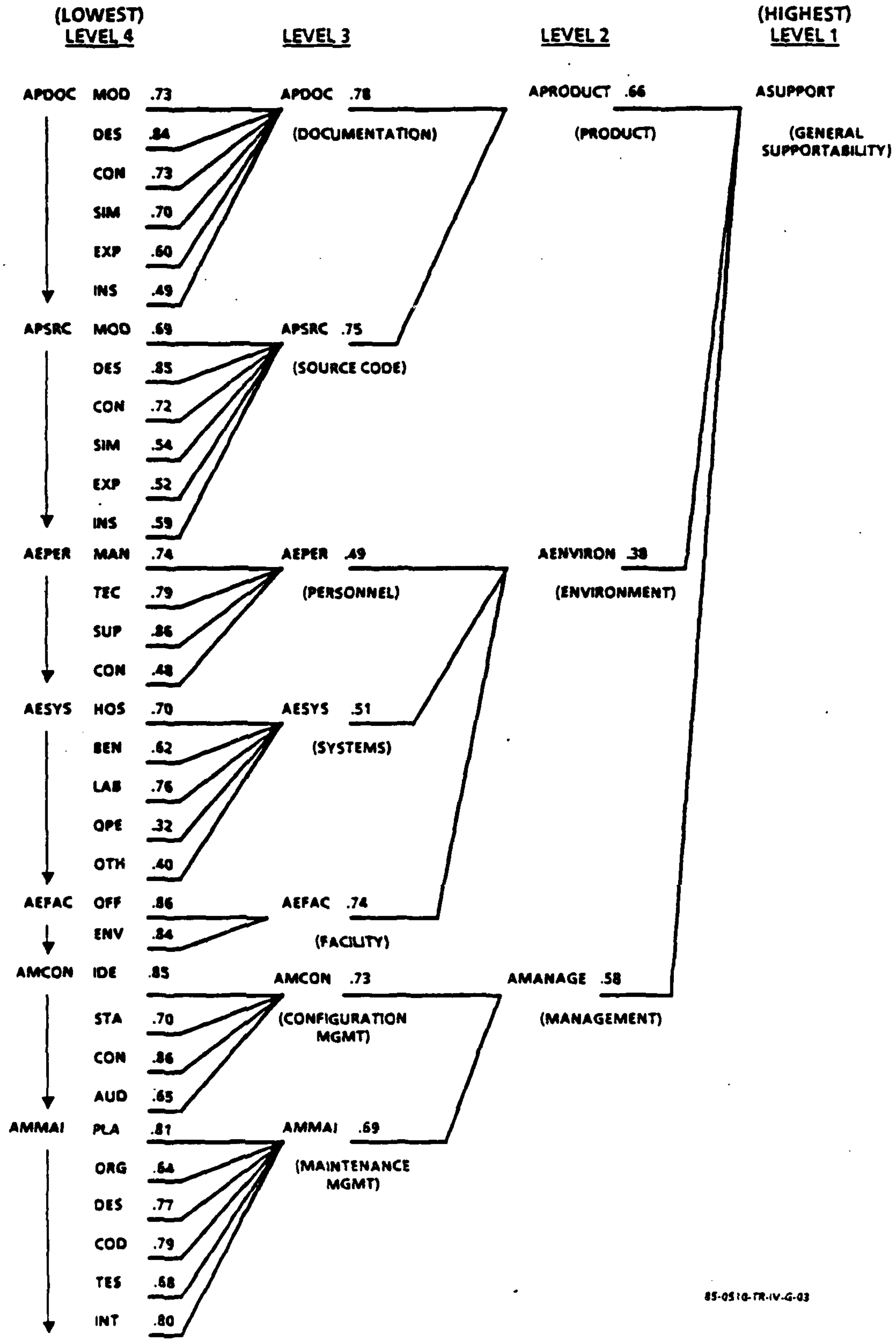


Figure 4-5. Correlation Coefficients For Pairs of Ratings Variables in Hierarchical Form of Survey Form

c. Note the general tendency for the correlations between levels to increase in going from the highest level (1) to the lowest level (4). This pattern reflects the organization of the survey form in that lower levels focus on more closely related supportability aspects than do higher levels.

d. The correlations in figure 4-5 were computed by the BMDP program BMDPAM, using a "smoothing" technique that compensates for missing values in the data set, so while these correlations are for the most part close to correlations obtained for the subset of data analyzed in the following sections, they are not identical. These smoothed correlations do serve, however, to illustrate the hierarchical structure just discussed. In the following analysis, some of the variables listed here will be omitted due to a large number of missing values.

4.4.2.1 Analysis Approach.

a. The technique used in this analysis to consolidate the many supportability ratings is known as factor analysis. Because there are so many (44) supportability rating variables deriving from the survey form, it is extremely difficult to grasp directly from the ratings data the relationships among the rating variables. One important feature of factor analysis is that it provides a systematic method for reducing the dimensionality of a large set of variables by producing a small set of factors that retain a large portion of the information content of the original variables. Another notable feature of factor analysis is that it can be used to discover linear relationships among the variables and to suggest the identity of basic underlying variables that the factors represent.

b. The mathematical model for factor analysis is

$$X_1 = \lambda_{11} Y_1 + \dots + \lambda_{1m} Y_m + e_1$$

$$X_2 = \lambda_{21} Y_1 + \dots + \lambda_{2m} Y_m + e_2$$

$$\cdots\cdots\cdots\cdots\cdots\cdots$$

$$X_p = \lambda_{p1} Y_1 + \dots + \lambda_{pm} Y_m + e_p$$

where $X_1, \dots, X_p$ are the p original variables, $Y_1, \dots, Y_m$ are the m (unobservable) factors, λ_{ij} is the so-called loading of the i-th variable on the j-th factor (actually, λ_{ij} is the correlation of the i-th variable with the j-th factor), and e_j is a random component. For a complete description of factor analysis, see chapter nine of Morrison (1976) (reference 8.18); chapter 8 is also relevant.

c. Computations for this factor analysis were accomplished using the BMDP Statistical Software factor analysis program BMDP4M. See the BMDP manual (1983) (reference 8.17) for details on the BMDP4M program.

d. Once the factor loading matrix is estimated, orthogonal transformations of the loading matrix sometimes yield loading vectors that are more readily interpretable in the subject context but retain their ability to model the original variables. These orthogonal transformations result in a rigid rotation or reflection of the coordinate axes of the m-dimensional factor space, hence the transformed loadings are referred to as "rotated factor loadings."

e. The next section discloses key results of the factor analysis performed on the evaluation data.

4.4.2.2 Results.

a. The factor analysis of the evaluation data was begun by deciding what supportability rating variables should be included. For some variables, such as APDOCINS, so many of the total of 97 data cases (from 97 completed evaluation survey forms) had missing values (no entry made by the evaluator) that deletion of those cases would have left too few cases to perform the analysis. Since estimating the missing data seemed inappropriate, the only alternative was to omit such variables from the analysis. In selecting variables to be omitted, the goal was to keep as many variables as possible in the analysis while maintaining a fairly large set of cases. The result of this process was that 7 variables were eliminated: APDOCINS, APSRCINS, AEPERCON, AESYSBEN, AESYSLAB, AESYSOPE, AESYSOTH. Listed in figure 4-6 are the remaining 37 variables. Of the 97 original data cases, 70 were complete in the 37 variables and were used in the analysis.

b. Figure 4-6 shows rotated factor loadings for 6 factors. Since the number of factors needed to appropriately describe this data set was initially unknown, loading matrices for models ranging from 4 to 9 factors were examined for interpretability. The 6-factor model was chosen because it accounts for 79 percent of the total variance of the 37 rating variables, and it yields factors that are, overall, more clearly interpretable than those of any of the other models. Interpretations assigned to the six supportability factors are given below in table 4-4.

c. The interpretations were arrived at by noting for each factor which variables had loadings of .5 or greater (these are flagged by asterisks in figure 4-6) and characterizing the quality that those variables collectively seem to measure. All the interpretations are straightforward except for that of factor 4, which is less so. It is interesting to note that rating variables that are related by virtue

ROTATED FACTOR LOADINGS

		FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6
AFOOC	3	0.138	0.743*	0.091	0.369	0.207	0.202
AFOOCMOD	4	0.189	0.541*	0.239	0.654 *	0.019	0.013
APOOCDES	5	0.289	0.729*	-0.003	0.024	0.297	0.192
APOOCCON	6	0.308	0.595*	0.264	0.422	0.206	-0.161
APOOCSIM	7	0.153	0.689*	0.002	0.057	0.055	0.285
APOOCEXP	8	-0.111	0.476	0.341	0.459	-0.083	0.084
APSRC	10	0.358	0.726*	0.259	0.172	0.176	0.026
APSRCMOD	11	0.236	0.566*	0.222	0.608 *	-0.054	-0.141
AFSRCDES	12	0.364	0.767*	-0.010	0.021	0.215	-0.057
AFSRCCON	13	0.225	0.717*	0.152	0.242	0.223	-0.177
AFSRCSIM	14	0.018	0.810*	0.014	-0.017	0.014	0.170
APSRCEXP	15	-0.148	0.670*	0.522 *	0.027	-0.021	0.085
APRODUCT	17	0.204	0.820*	0.246	0.159	0.089	0.213
AEPER	18	0.370	0.181	0.815 *	0.207	0.180	0.085
AEPERMAN	19	0.510*	-0.032	0.542 *	0.341	0.238	0.011
AEPERTEC	20	0.224	0.128	0.855 *	0.117	0.092	0.036
AEPERSUP	21	0.286	0.168	0.802 *	0.296	0.074	0.049
AESYS	23	0.142	0.352	0.408	0.087	0.282	0.588 *
AESYSHOS	24	0.011	0.284	0.036	0.075	0.218	0.844 *
AEFAC	29	0.168	0.136	0.057	-0.039	0.937 *	0.117
AEFACOFF	30	-0.057	0.123	0.061	0.300	0.890 *	-0.047
AEFACENV	31	0.272	0.219	0.103	-0.054	0.771 *	0.329
AENVIRON	32	0.337	0.240	0.285	0.058	0.768 *	0.143
AMCON	33	0.621*	0.215	0.193	0.623 *	0.023	-0.127
AMCONIDE	34	0.400	0.153	0.083	0.733 *	0.158	0.000
AMCONSTA	35	0.864*	0.103	0.025	0.134	-0.036	-0.144
AMCONCON	36	0.804*	0.231	0.127	0.334	0.119	-0.100
AMCONAUD	37	0.876*	0.101	-0.013	0.063	0.094	-0.122
AMMAI	38	0.708*	0.270	0.351	0.301	0.232	0.223
AMMAIPLA	39	0.693*	0.137	0.357	0.271	0.254	0.179
AMMAIORG	40	0.212	-0.026	0.219	0.736 *	0.103	0.300
AMMAIDES	41	0.663*	0.360	0.389	0.151	0.133	0.178
AMMAICOO	42	0.530*	0.466	0.423	0.013	0.185	0.160
AMMAITES	43	0.754*	0.243	0.189	-0.079	0.101	0.273
AMMAIINT	44	0.710*	0.147	0.307	0.148	0.130	0.101
AMANAGE	45	0.725*	0.144	0.189	0.390	0.278	0.297
ASUPPORT	46	0.515*	0.450	0.418	0.130	0.076	0.261

Figure 4-6. Rotated Factor Loadings

of the hierarchy in the survey form tend to load heavily on only one factor, indicating that relationships intended in the survey form are reflected in the data.

Table 4-4.

Interpretations of Supportability Factors

FACTOR NUMBER	INTERPRETATION
1	Support Management
2	Product
3	Personnel
4	Organization
5	Facilities
6	Support Systems

d. The basic accomplishment of this factor analysis is that the dimensionality of the supportability rating data has been reduced from 37 variables to 6 factors having reasonable and useful interpretations. With most of the information content of the original variables consolidated into the factors, the factors can be used in subsequent analyses in place of the variables, as will be shown in the next section.

e. Although some subjective choice was involved in the development of the factor model, the model is applied consistently across all data cases, and it therefore represents an improvement over the general supportability rating above, which--as discussed in section 4.4.2--is based on a different unknown model for each case (i.e., evaluator). The factor model represents a further improvement in that the factors incorporate the general supportability rating variable, ASUPPORT.

4.4.3 The Relationship Between Risk Rating and Supportability Factors.

In section 4.4.2, the numerous supportability rating variables were consolidated into six factors. The purpose of this section is to examine and characterize the relationship between risk rating and the supportability factors named in table 4-4. Of particular interest is the question of which factors figure into an evaluator's determination of risk, and to what degree.

4.4.3.1 Analysis Approach.

a. Results presented in the next section were obtained through regression analysis. The mathematical model for this regression analysis is

$$Y = b_0 + b_1X_1 + \dots + b_6X_6 + e,$$

where Y = the risk rating (transformed),
X_i = the score for the i-th factor,
e = a random component,

and the regression coefficients $b_0, \dots, b_6$ are parameters to be estimated. (The X_i here are equivalent to the Y_j in the factor analysis model of section 4.4.2.1, not to the X_i of that model.) The risk rating variable, R, is transformed via the transformation L(R) described in section 4.4.1.2--for reasons discussed there--to obtain the dependent variable Y above.

b. An alternative approach that might be tried would be to use as the independent variables X_i in the above model the supportability rating variables, instead of the factors derived from them. Such an approach, however, would result in an unwieldy model with 37 independent variables. Of course, a small subset of those variables could be selected for inclusion in the model, but the variable selection

itself then becomes problematic insofar as most of the variables--and the information they may contain--would be discarded. Use of factors as independent variables avoids this dilemma because the factors each incorporate, to greater or lesser degree, information from all of the rating variables, with each factor (as shown by the factor loadings in figure 4-6) emphasizing a different subset of the rating variables. Furthermore, the factor-based regression model is far more parsimonious and therefore more easily interpreted.

c. The same 70 data cases used to construct the factors obtained in section 4.4.2.2 were used in conducting the regression analysis of this section. For each case, the factor scores X_i were computed from the rating variables, and to those data, along with the transformed risk ratings Y, the above regression model was fitted. Results appear in the next section.

4.4.3.2 Results.

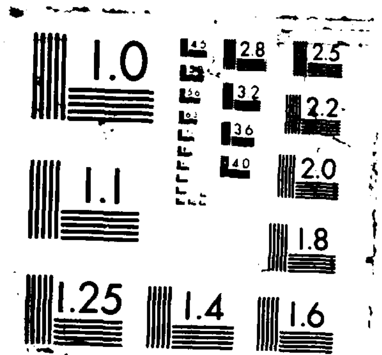
a. Results for the regression analysis of transformed risk versus the six supportability factors are shown in figure 4-7. These results were generated by the BMDP program BMDP1R: Multiple Linear Regression. The dependent variable, transformed risk ($Y = L(R)$), has the variable name LRISK in the figure. In the analysis of variance table near the middle of figure 4-7, the F statistic testing the significance of the regression model is 8.163 (under the column heading "F RATIO"), a value significant at the 0.0001 level, indicating that the regression coefficient for at least one of the factors is significantly different from zero. Examination of the table at the bottom of figure 4-7 shows that t statistic values (in the column labeled "T") for the coefficients of four of the factors have significance probabilities (the column labeled "P(2 TAIL)") less than .05. The three factors are thus significant at the .05 level; they are flagged by asterisks to the left of their variable names in the column labeled "VARIABLE". The variable names are obvious abbreviations of the interpretive labels given to the factors in table 4-4.

```
  REGRESSION TITLE IS
LRISK VS. ALL FACTORS

  DEPENDENT VARIABLE. . . . . . . . . . . . . . .      48 LRISK
  TOLERANCE . . . . . . . . . . . . . . . . . . .  0.0100
ALL DATA CONSIDERED AS A SINGLE GROUP

MULTIPLE R              0.6614        STD. ERROR OF EST.        1.7616
MULTIPLE R-SQUARE       0.4374

ANALYSIS OF VARIANCE
                     SUM OF SQUARES      DF     MEAN SQUARE          F RATIO    P(TAIL)
          REGRESSION       151.9866       6         25.3311           8.163     0.0000
          RESIDUAL         195.4984      63          3.1031

                                                STD. REG
   VARIABLE         COEFFICIENT    STD. ERROR     COEFF          T   P(2 TAIL) TOLERANCE

  INTERCEPT           -0.72283
 *SUPPMGT     49      -0.61497      0.21207      -0.274     -2.900     0.0051     1.00000
 *PRODUCT     50      -0.71779      0.21207      -0.320     -3.385     0.0012     1.00000
 *PERSONEL    51      -0.43993      0.21207      -0.196     -2.074     0.0421     1.00000
  ORGANZTN    52       0.17999      0.21207       0.080      0.849     0.3592     1.00000
  FACILITY    53       0.21084      0.21207       0.094      0.994     0.3239     1.00000
 *SUPPSYS     54      -1.01927      0.21207      -0.454     -4.806     0.0000     1.00000
```

Figure 4-7. Results for Regression Analysis of (Transformed) Risk Versus Supportability Factors

AD-A190 283 SOFTWARE SUPPORTABILITY RISK ASSESSMENT IN OT&E 2/3
(OPERATIONAL TEST AND EVA..(U) BDM CORP ALBUQUERQUE NM
D E PEERCY ET AL. 07 OCT 85 BDM/A-85-0510-TR-VOL-1

UNCLASSIFIED F29601-80-C-0035 F/G 5/1 NL


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

b. The interpretation given to these results is that the four supportability factors called Support Management, Product, Personnel, and Support Systems figure significantly in the evaluators' assessment of risk; the other two factors--Organization and Facilities--do not (at least for the evaluators represented in this data set). Estimates of the regression coefficients $b_1, \ldots, b_6$, are printed in the second column (labeled "COEFFICIENT") of the table at the bottom of figure 4-7. Note first that the coefficients of the significant factors are all negative. This means that higher scores for those factors are associated with lower transformed risk values--and correspondingly, with lower risk ratings. Conversely, lower factor scores are associated with higher risk ratings. The magnitudes of the coefficients indicate the relative strengths of the corresponding factors in this association; hence "support systems" is in this sense the most important factor in rating risk, followed by product, support management, and personnel.

c. Finally, the above fitted regression model has an R^2 statistic (labeled "MULTIPLE R-SQUARE" in figure 4-7) of .4374, which indicates that the model accounts for about 44 percent of the variation of the transformed risk values about their mean. This R^2 value is quite low. An alternative view is that the model fails to account for the other 56 percent of the variation. Evidently, there are other aspects not assessed in the survey form that bear on risk rating, or there is a set of factors that might be better than the selected six factors, or perhaps more likely, there is just a great deal of variation among evaluators in their rating of risk.

4.4.4 Comparison of Metric-to-Risk Conversion Methods.

a. In sections 4.4.1.1 and 4.4.1.2, two methods were described whereby the general supportability metric (rating) could be converted to risk. The first of these methods is referred to as a simple linear conversion function, the second as a linear regression

approach. Those two methods were compared in section 4.4.1.2, specifically in figure 4-4. That comparison showed that the linear regression method better represents the data collected. Although application of the linear regression method is somewhat more involved that that of the simple linear conversion method, the calculations are still easy enough to do on a hand calculator. For quick approximations of risk from the general supportability metric, the linear regression approach may be used, as long as the user remains aware of the error potential evident in the scatter of data about the prediction lines shown in figures 4-3 and 4-4.

b. The factor regression model developed in section 4.4.3 is the most accurate means devised here for predicting risk from supportability metrics. Figure 4-8 is a plot of transformed risk values (LRISK) versus the rating on the general supportability metric (ASUPPORT). This plot is basically the same as that of figure 4-3, with the straight line drawn through the scatter of data again representing the regression on the general supportability metric. The points indicated by "O" in the plot are actually observed data values, those indicated by "P" are predicted from the regression on the supportability factors, and those indicated by an asterisk are coincidences (to within the resolution of the plot) between observed and predicted transformed risk values. From the plot, it is clear that the factor regression model better represents the data than does the general supportability metric regression model. This conclusion is confirmed by the fact that the R^2 value for the factor model is higher than that for the general supportability metric model (.44 as compared to .35).

c. A drawback to the model using supportability factors, however, is that its application is computationally intensive and therefore not suited to a hand calculator. Two lengthy steps are required to use that model in predicting risk. First, scores for each of the six factors must be computed from one of six different linear

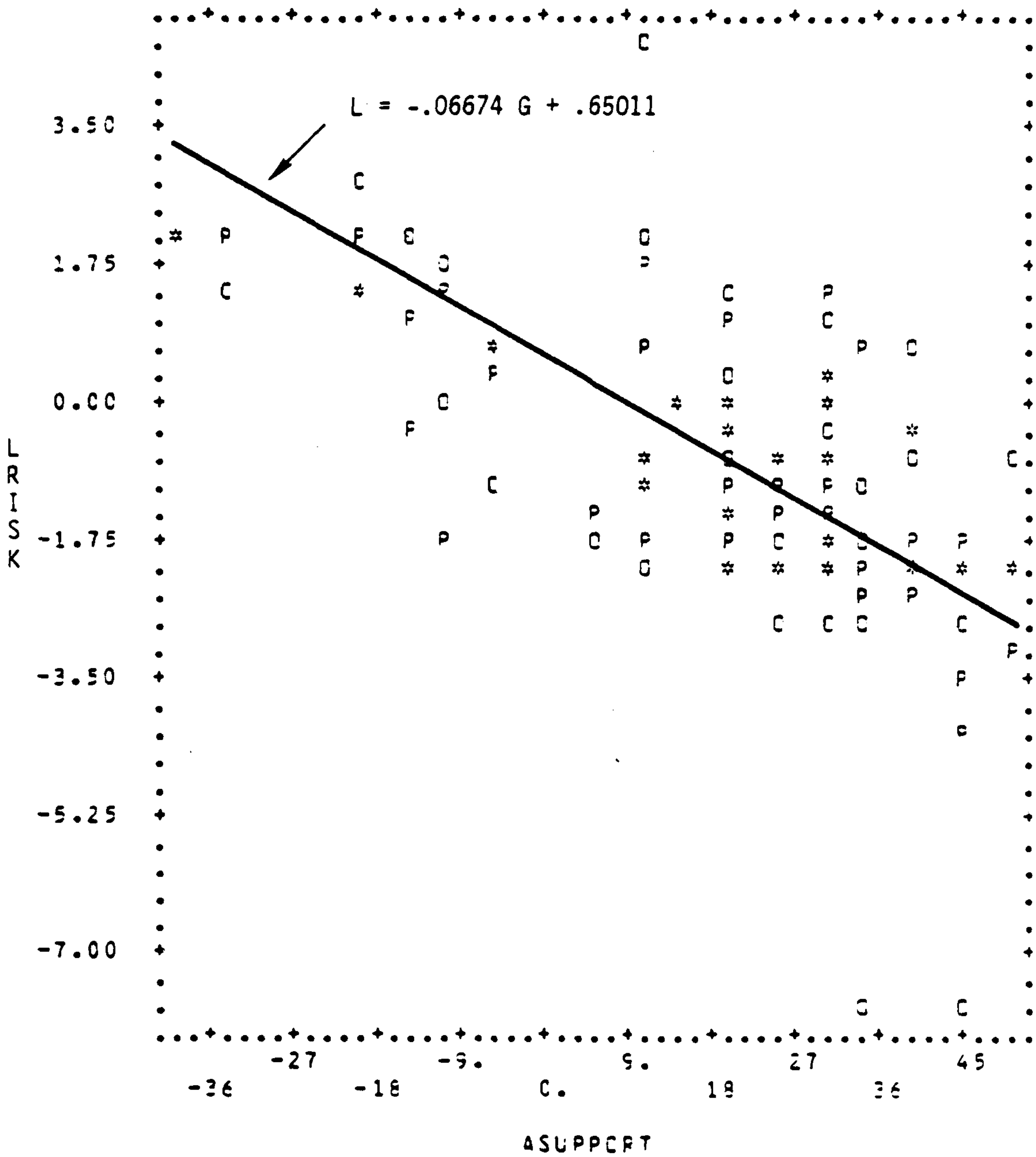


Figure 4-8. Comparison of Regression on General Supportability Metric with Regression on Supportability Factors

functions having 37 terms, one per supportability metric. Second, the factor scores must be substituted into the regression model of section 4.4.3.2 to compute transformed risk. The last step, detransforming the transformed risk value to a risk value is the same for either regression model. Although this procedure is too tedious for hand calculation, it could be implemented for quick and easy use on a computer.

4.5 MAINTENANCE DATA ANALYSIS.

a. The primary objective of collecting the maintenance activity data is to generate a historical data base from which baseline support profiles can be created. Because it was not clearly specified by the preliminary methodology (reference 8.3) how such data would be used to create the required profiles, there was the need to establish this relationship. Another important factor to be integrated is "reality" - that is, what is really possible?

b. Because of the above considerations, the reduction of the collected data to some most common denominator became a primary concern of the analysis. It was necessary to integrate the data being collected at each site and determine what could be done with reasonable resources such as would be available during a normal system OT&E, and which data was likely to be common with the systems to be surveyed in the future. In short, the survey was an evolving, lessons learned, learning curve experience. The methodology impact of this analysis is presented in section VI, including an extended example. The analysis comments presented in this section include data items of most interest, availability of the data, consistency and accuracy of the data, ways to improve the validity of the data, regression analysis of baseline profile factors, and general conclusions/observations.

4.5.1 Summary Observations on Collected Maintenance Data.

4.5.1.1 Software Release Data Items of Interest. Major software maintenance parameters of interest include:

(1) Block release start date, engineering completion date, field date

(2) Number of personnel assigned to each block release and percentage of the time these personnel are dedicated to the release

(3) Skill level of personnel assigned to block release

(4) Estimated level of resource requirements (personnel and systems) for block release: at start date

(5) Actual level of resources consumed (personnel and systems) for block release: at engineering completion date

(6) For each change request in the block release, the type, complexity, priority, estimated and actual resource requirements, configuration control dates

All of this data should be available through a computerized, configuration management, status accounting function. No system had all the information available in an easily accessible form. Appendix D contains a list of the systems and the release data items which were collected. Some general statistics of interest pertaining to the maintenance release data are presented in table 4-5.

4.5.1.2 Availability of Data.

a. Data was collected from nearly all possible personnel and organizational "pieces" of a support organization. The formal

configuration management function at a given site would generally have summary data on each block release. The Air Force Form 75 is the formal mechanism for ALCs, but the data on these forms has a wide flexibility of format and meaning. Estimates of block release person effort broken into maintenance project, configuration management, test, IV&V, contractor, and overall management categories is available. Occasionally, the individual list of change requests incorporated into the block release is included. A schedule for the various block release phases is supposed to be attached. No information

Table 4-5.

Summary of Maintenance Release Data Statistics

SYSTEMS		
Total Number	- 81	
# OFP	- 32	
# EW	- 5	
# C-E/C3I	- 13	
# ATD/OFT	- 7	
# ATE	- 7	
# SIM	- 6	
# SUP	- 11	
BLOCK RELEASES		
Total Number Reported	- 336	
Number Useful for Profiles	- 278	
Number with TYPE Changes	- 308	
Number with COMPLEXITY Changes	- 175	
Number with PRIORITY Changes	- 311	
CHANGES *		
Total Number Reported	- 12789	
TYPE Changes		
Total Number Reported	- 12769	
# Corrections	- 9982	: % = 78
# Enhancements	- 2735	: % = 22
# Conversions	- 52	: % = 0
COMPLEXITY Changes		
Total Number Reported	- 7627	
# High Complexity	- 857	: % = 11
# Medium Complexity	- 2832	: % = 37
# Low Complexity	- 3938	: % = 52
PRIORITY Changes		
Total Number Reported	- 12789	
# Emergency	- 187	: % = 1
# Urgent	- 2627	: % = 21
# Normal	- 9975	: % = 78
COMPUTATIONS *		
Number of Changes Per Release	- 38	
Total Available Person Months	- 38631	
Available Person Months Per Change	- 3	

* - Minuteman releases (3) are not included in data

(other than the naming scheme for the requests) is available to stratify the change requests. The lower level detail such as type, complexity, priority, effort estimates and control dates for each change request is usually contained in working engineering notebooks. This latter information is not consistently recorded nor completely available for all systems.

b. Actual person effort for a block release was almost always unavailable. The complexity of each change request was not directly available. The stratification of change requests by the type "conversion" was almost always unavailable, despite the fact that conversions are being done all the time, and are frequently very complex. The conversions are generally included with enhancements for the maintenance activity data collected. The personnel resource data was obtained through subjective estimates by the support personnel. Most often only engineering release dates, and fielded dates were known. The release start date is usually not well-defined due to the nature of processing change requests. Where a standard cycle (e.g., 18 months) for block releases was known, the start date was estimated from the end dates. There is usually a long time (6 to 18 months) between completion of the maintenance engineering effort and the operational fielding of the software release. Hence, the end of the engineering effort (through OT&E phase functions) is the terminology used for the engineering completion date. The start date is when the bulk of the maintenance block release effort begins.

c. Despite the limitations of the available data, support personnel were frequently able to reconstruct some of the release data not readily available such as complexity level (high, medium, low), important release dates, and personnel resource data. As an example, the Ogden ALC F-16 and F-4 support personnel were able to provide complexity estimates to each change request in each release in a little less than a person day (several personnel working a little more than an hour apiece).

4.5.1.3 Consistency and Accuracy of the Data.

a. Part of the accuracy and consistency problems of the data reflect the lack of adherence to the model of software maintenance activity as described in section 3.2. Many systems had not been formally transferred to the support organization. Consequently, some data such as development contractor support data was not available, but some organic data was available. This has contributed to data inconsistency. The non-uniform support across organic, developer, and subcontractor personnel seemed to be rather prevalent at the ALCs, even for software systems (e.g., B-52, E-3A) which one would suspect have already been transferred and are under full ALC support responsibility.

b. The available person time was adopted for use in the development of baseline profiles because no other personnel effort data was uniformly available. Available person time for a block release is computed as the product:

$$APT = (NP)\ (PDS)\ (PDR)\ (DBR)$$

where: APT - Available person time (months)

NP - Number of persons assigned to software system

PDS - Percentage of the persons dedicated to the software system (versus shared time with other software systems)

PDR - Percentage of the persons dedicated to the block release (versus other block releases for this system)

DBR - Engineering duration of the block release (months).

c. Use of available person time leads to a variance in the data which can greatly affect the shape and accuracy of the profile curves. For example, using the limited amount of data on estimated and actual person effort available for block releases along with

information gathered during the survey interviews, the ratio of actual person effort in a block release to available person time ranged from 0.3 to 0.9. Thus, a value of 2.0 available person months per change for a given release might reflect a range in actual person months per change of 0.6 up to 1.8. This variance confirms that ALC personnel are being utilized at different capacities across different releases, perhaps depending upon change requirements. It may also account for the rather wide disparity in the available person months per change across releases for a given system and across different systems. It also indicates that a large amount of overhead (effort not directly attributable to software releases) is included in the available person time.

d. For example, in one release personnel could be utilized at 90 percent capacity to produce 50 changes over a 12-month engineering release period. In another release, personnel could be utilized at 30 percent capacity to produce 21 changes over a 12-month engineering release period. The actual productivity would be the same in these two cases. The available person time per change would be significantly different, reflecting the variance in overhead.

e. These observations simply support normal expectations. The importance of the data is to provide some boundaries and guidelines upon which some better decisions can be made. The observation of the 30 to 90 percent utilization variance would be very valuable if it could be validated. The data for the available person time is somewhat inaccurate since it was not always possible to determine precisely how many persons were assigned to a given release. The general assumption that personnel are assigned in some uniformly dedicated percentage of time to a system and to a release is obviously not correct, except as a first approximation. However, using the available person time should give a reasonable upper limit to the risk estimation. This would allow for some tradeoffs such as assuming a larger apparent risk in anticipation of greater utilization of personnel.

f. Collected data items which were very accurate (perhaps within 5 percent error) included the total number of changes, number of corrections, and number of non-corrections (enhancements plus conversions) in each block release. An interesting observation (from table 4-5) is that the percentage of corrections (78 percent) is much higher than the percentage of non-corrections (22 percent). A brief analysis of the available effort data seems to indicate more effort is spent on an average enhancement than on an average correction, but not enough to cause the percentage of effort spent on enhancements to be more than on corrections. This data seems to contradict the generally accepted results from the Lientz-Swanson research (references 7.11 and 7.12) and several other research efforts. The research results indicate that the support effort is divided across corrections, enhancements, and conversions at the respective percentages 20 percent, 60 percent, and 20 percent. The results are primarily based upon subjective responses from ADP software support managers, but the concept of "more effort is spent on enhancements than corrections during software maintenance" is well accepted within the military software support community. Because of the lack of overall data consistency, no certain conclusions can be made, but this observation would be interesting to revisit if actual effort data by change request were collected in the future so that a statistical analysis could be performed.

4.5.1.4 Techniques to Improve Data Validity. There are many techniques to improve the validity of data such as has been gathered during the survey visits of this study. The primary techniques which have been used during the evolution of the survey process include:

(1) Delphi-feedback. By asking the sources of data for updated, more accurate data based upon better terminology and review of similar data from other sources, the validity of the data is improved.

(2) Calibration. More careful explanation of the terminology, use of the data, and expected relationships of the data should improve the validity of the data.

(3) Evaluation Time. The nature of the survey process meant the evaluators were greatly constrained in evaluation time. The more normal evaluation procedure may still be constrained, but will improve the validity of the data.

4.5.1.5 General Conclusions/Observations.

a. The bottom line is whether the results of the maintenance (release) data analysis supports and/or improves the current risk assessment methodology. The analysis of the data indicates that the methodology has been improved, made more realistic, and is now capable of an actual application pilot study (see chapter VI).

b. The maintenance data collection must be standardized and a central data repository established before very much accuracy and consistency of the data can be realized. Recommendations on how this might be done are presented in section 3.6.

c. The baseline support profile agreement between user and supporter must be integrated into the life cycle acquisition process. This is important to the success of the RAMSS concept.

d. Results of current statistical analysis is presented in the following sections.

4.5.2 An Examination of Variables Potentially Associated with Available Person Time.

a. With the maintenance data collected for this effort, available person time could be characterized in either of two ways: as person

time <u>per</u> <u>release</u> or as person time <u>per</u> <u>change</u>, where a <u>change</u> is the elemental unit of software modification within a release consisting of multiple changes. Person time per change is merely the total available person time for a release divided by the total number of changes comprising the release. Use of person time per change offers the advantage that it tends to normalize all the releases to a common basis. Comparison of releases is difficult on a person time per release basis, because the number of changes in each release must be accounted for. In this data set, the number of changes per release varies from one to hundreds, making comparisons between releases on a person time per release basis quite complicated. For this reason, person time per change was chosen as the variable to represent available person time in this study. The units of time used throughout are months, so that the variable, person time per change, becomes person months per change (PMPC).

b. Along with available person time, many other items of information were collected on software systems and on the block releases of software changes associated with those systems. Two key pieces of information used in developing the maintenance profiles of section V are the type of software system and the site at which the system software is maintained. In section V, separate maintenance profiles (histograms showing the frequencies of available PMPC values) are given for each site and software system type. As was anticipated before any data were collected, there are substantial differences in PMPC among the various software types and sites; hence, software type and site are two variables that are apparently associated with PMPC. Other variables thought to be potentially associated with PMPC were:

(1) PTCORR - the proportion of changes of correction type

(2) PCLOW - the proportion of changes of low complexity

(3) PPNORM - the proportion of changes of normal priority

(4) KLINES - the number of K-lines (thousands of lines) of source code in the software system being maintained

(5) PCHILEV - the percentage of high-level computer languages (languages other than assembly) used in the source code

(6) AVGSKILL - the average skill level of the software maintenance personnel (derived from system background data collected on the survey forms--see appendix C).

c. Before proceeding with an analysis of the variables listed above, it is appropriate to present for orientation purposes some summary information on the releases for which data was obtained. Figure 4-9 is a chart showing the counts of releases for which data was obtained in each software type and at each site. These counts reflect all the data records, or cases, stored in the dBASE III database RLS_SMRY.DBF, *including those cases that will be discarded for* the analysis that follows because they lack data for one or more of the variables needed or are otherwise inappropriate for inclusion in the analysis. The software type and site abbreviations are defined in tables 5-1 and 5-2 of section V. Note that the pattern of non-empty cells in the matrix is quite sparse, and counts within the cells vary from 1 to 110. Also, the marginal counts for two groups are quite low: software type SIM and site CASTLE had only 5 and 6 releases, respectively From the counts in the cells, it is apparent that almost all of the 8 sites are dominated by releases in a single type of software; thus, the differences in PMPC that are seen among sites in the maintenance profiles of section V may be primarily attributed to differences among software types. For this reason, the analysis of the next two sections will use software type as a variable, but not site.

SITE	SOFTWARE TYPE							
	ATD	ATE	C-E	EW	OFP	SIM	SUP	TOTAL
NORAD			110					110
WR-ALC		9	2	24	6	2	1	44
SM-ALC					17			17
CASTLE	6							6
OO-ALC	3				34	3		40
OC-ALC	1	7			24		5	37
TINKER			19				14	33
LANGLEY	1		40				8	49
TOTAL	11	16	171	24	81	5	28	336

85-0510-TR-W-IV-01

Figure 4-9. Counts of Releases in Raw Data by Site and Software Type

4.5.2.1 Analysis Approach.

a. The purpose of this analysis is to determine whether a proposed mathematical model involving variables in addition to software type can be used to predict PMPC more effectively than does a model involving only software type. This statement presupposes that software type is useful is predicting PMPC, something that has not yet been demonstrated but will be in the analysis. The additional variables to be used are those listed above in section 4.5.2. Should some of these variables prove to be useful in predicting PMPC, then a model incorporating them could be exploited to provide improved estimates of the supportability risk associated with a particular software system.

b. The proposed model is a linear regression model of the form

$$Y = b_0 + b_1X_1 + \dots + b_6X_6 + a_1 + \dots + a_{t-1} + e,$$

where

Y = the logarithm of person months per change (PMPC),
X_i = the i-th covariate (one of the 6 variables above),
b_i = the regression coefficient for the i-th covariate,
a_j = an indicator variable for the j-th software type,
t = the number of different software types,
e = a random component.

The logarithm of PMPC is used as the dependent variable, Y, in this model, because preliminary examinations of the data indicated differences in the variance of PMPC between the software types--differences of a nature that the logarithm transformation is known to alleviate in many situations. There are t - 1 software-type indicator variables in this model instead of t, because the intercept b_0 accounts for the t-th software type.

c. This model is an analysis of covariance type model in regression form. The idea underlying the model is that a given software type has an average (mean) PMPC value that, in general, is different from those of the other software types. In addition, the covariates contribute to differences in PMPC, so that two systems of a given software type but of different sizes (KLINES), for example, will be expected to have different predicted PMPC values.

4.5.2.2 Results.

a. In fitting the regression model of section 4.5.2.1, not all of the cases of data that were collected were used. Of the 336 total cases collected, 29 were for releases having only one software change; they were omitted because such releases are atypical and do not conform to the concept of releases made up of multiple changes. Another 63 cases were omitted because they were missing data for variables required in the analysis. Finally, all 5 cases for the

software type SIM were omitted due to strong indications of irregularities in the data. The remaining 239 complete cases were used in the analysis.

b. Results for the full regression model of the preceding section appear in figure 4-10. The six software types (t = 6 in the model, since the type SIM was left out) collectively account for a significant portion of the variation in Y (this was ascertained in an analysis of variance table not shown here). Of the six covariates, though, only one, PTCORR, is shown to have a regression coefficient significantly different from zero, as evidenced by the significance probability of 0.0036 under the column heading "P(2 TAIL)" in the table at the bottom of figure 4-10. However, even this significant result for a covariate is questionable, since one of the diagnostic plots investigated for these results shows rather clearly that an increase in the <u>variance</u>, not a decrease in the <u>mean</u>, of Y is probably creating a spurious significant result. Further analysis could be done to check this assertion.

c. The R^2 statistic for this model is a very low .2656, implying that the model is unable to explain the majority of the variation of Y about its mean. This situation may be attributed largely to the coarse nature of the data. While considerable care was taken in collecting and processing the data, no amount of care could change that fact that, in most cases, data of the form desired for this study simply did not exist, and coarser surrogate data had to be used. No doubt further analysis might yield greater insights into this data, but for now there is little evidence that any of the covariates examined here have a consistent bearing on PMPC.

d. The above-mentioned statistical significance of the software types implies that at least two of the software types have significantly different mean values of Y. Since the logarithm transformation used to get Y is a monotone function, the inference may also be

```
  REGRESSION TITLE IS
SW TYPE DUMMY VARIABLES PLUS COVARIATES


  DEPENDENT VARIABLE. . . . . . . . . . . . . . . .      41 LN(FMPC)
  TOLERANCE . . . . . . . . . . . . . . . . . . . .  0.0100
ALL DATA CONSIDERED AS A SINGLE GROUP

MULTIPLE R             0.5154          STD. ERROR OF EST.          0.9284
MULTIPLE R-SQUARE      0.2656

ANALYSIS OF VARIANCE
                    SUM OF SQUARES     DF     MEAN SQUARE       F RATIO    P(TAIL)
         REGRESSION         70.7765     11          6.4344        7.465     0.0000
         RESIDUAL          195.6633    227          0.8620
```

VARIABLE		COEFFICIENT	STD. ERROR	STD. REG COEFF	T	P(2 TAIL)	TOLERANCE
INTERCEPT		-1.75334					
PTCORR	30	-0.79635	0.27028	-0.208	-2.946	0.0036	0.64885
PCLOW	35	-0.25261	0.25032	-0.079	-1.009	0.3140	0.52714
PFNCRM	38	0.42919	0.30487	0.140	1.408	0.1606	0.32726
KLINES	25	0.65764E-04	0.11496E-03	0.050	0.607	0.5446	0.48125
PCHILEV	26	-0.00149	0.00211	-0.058	-0.705	0.4813	0.47522
AVGSKILL	27	0.19191	0.10307	0.114	1.862	0.0639	0.86444
ATD	42	1.73008	0.53209	0.256	3.251	0.0013	0.52047
ATE	43	2.66001	0.46544	0.592	5.719	0.0000	0.30188
C-E	44	2.63831	0.38292	1.241	6.890	0.0000	0.09566
EW	45	2.11575	0.43411	0.567	4.874	0.0000	0.23879
OFP	46	1.90142	0.38107	0.767	4.990	0.0000	0.13675

Figure 4-10. Results for Regression Model Involving Software Types and Covariates

made that at least two of the software types differ in PMPC. Therefore, it is advisable when using the maintenance profiles of section V to estimate risk that the separate profiles for the software types be used instead of the all-inclusive profile in which data for all the software types are lumped together.

V. Maintenance Profiles

SECTION V

MAINTENANCE PROFILES

5.1 GENERAL DESCRIPTION OF MAINTENANCE PROFILES.

a. The parameters plotted for the historical maintenance profiles are the available person-months per change on the x-axis and the number of releases on the y-axis. The x-axis consists of discrete intervals. The resulting plot thus is a frequency histogram with each rectangular "box" representing the number of releases for which the available person-months per change fell within the discrete interval on the x-axis at the base of the "box." Figure 5-1 shows a generic example of a maintenance profile.

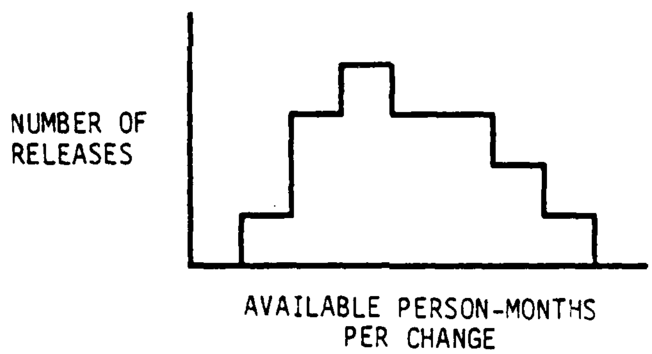


Figure 5-1. Generic Maintenance Profile (Histogram) for Available Person-Months per Change

b. Available person-months per change is defined in the glossary and explained in more detail in section 4.5. There are a variety of other parameters which could constitute the x-axis parameter for maintenance profiles, but this one was chosen for reasons explained in section 4.5.2.

c. All historical maintenance profiles contained in the remainder of this section were produced by the BMDP statistical analysis program resident on a VAX 11/780 computer.

5.2 MAINTENANCE PROFILES: ALL SYSTEMS.

a. A historical maintenance profile for block releases over all systems for which the necessary data were collected is shown in figure 5-2. The histogram in figure 5-2 is oriented somewhat differently than that in figure 5-1. It has been rotated clockwise by 90 degrees so that the available person-months per change (PMPCHNG) interval values appear on the vertical axis and the frequency, or number, of releases appears on the horizontal axis. Each "X" in the plot represents 1 release (referred to as an "observation" at the top of the plot). The numerical values listed along the vertical axis under "INTERVAL NAME" are upper limits of the PMPCHNG intervals. For example, 36 releases had PMPCHNG values greater than 0 and less than or equal to 1. The four columns of numbers at the right of the histogram are, respectively, frequencies for the intervals, cumulative frequencies, percentages of the total release count for the intervals, and cumulative percentages.

b. At the top of figure 5-2 are printed three statistics of interest. They indicate that there were 280 releases (of a total of 336 for which some data were gathered) for which sufficient data were obtained to allow calculation of available person-months per change and which had more than one change. Releases having only one change were judged to be inconsistent with the idea of a release having multiple changes; furthermore, many of the single-change releases were found to be extraordinary in several respects from the bulk of multiple-change releases. For these 280 releases, the overall mean (average) available person-months per change was 3.853 with a standard deviation of 3.585.

c. To further exemplify the use of the profile, note that 65 releases (23.2 percent of the 280) had PMPCHNG values greater than 1 and less than or equal to 2, and 101 releases (36.1 percent) had values less than or equal to 2. Only 6.4 percent (100 percent minus 93.6 percent) of the releases had PMPCHNG values exceeding 10.

```
HISTOGRAM OF VARIABLE   29 PMFCHNG
                                     SYMBOL  COUNT      MEAN      ST.DEV.
                                       X      280       3.853      3.585
                         EACH SYMBOL REPRESENTS          1 OBSERVATIONS
INTERVAL                                                                       FREQUENCY PERCENTAGE
NAME          5    10   15   20   25   30   35   40   45   50   55   60   65  INT.  CUM.  INT.  CUM.
         +----+----+----+----+----+----+----+----+----+----+----+----+----+
*1.00000 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX                                  36    36  12.9  12.9
*2.00000 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX         65   101  23.2  36.1
*3.00000 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX                   55   156  19.6  55.7
*4.00000 +XXXXXXXXXXXXXXXXXXXXXXXXXXX                                           27   183   9.6  65.4
*5.00000 +XXXXXXXXXXXXXXXXXXXXXXXXX                                             25   208   8.9  74.3
*6.00000 +XXXXXXXXXXXXXXXXXXXX                                                  20   228   7.1  81.4
*7.00000 +XXXXXXXXXXXXX                                                         13   241   4.6  86.1
*8.00000 +XXXXXX                                                                 6   247   2.1  88.2
*9.00000 +XXXXXXX                                                                7   254   2.5  90.7
*10.0000 +XXXXXXXX                                                               8   262   2.9  93.6
*11.0000 +XXXXXX                                                                 6   268   2.1  95.7
*12.0000 +XX                                                                     2   270   0.7  96.4
*13.0000 +XXX                                                                    3   273   1.1  97.5
*14.0000 +                                                                       0   273   0.0  97.5
*15.0000 +XXX                                                                    3   276   1.1  98.6
*16.0000 +X                                                                      1   277   0.4  98.9
*17.0000 +X                                                                      1   278   0.4  99.3
*18.0000 +                                                                       0   278   0.0  99.3
*19.0000 +                                                                       0   278   0.0  99.3
*20.0000 +                                                                       0   278   0.0  99.3
*21.0000 +                                                                       0   278   0.0  99.3
*22.0000 +                                                                       0   278   0.0  99.3
*23.0000 +X                                                                      1   279   0.4  99.6
*24.0000 +                                                                       0   279   0.0  99.6
*25.0000 +X                                                                      1   280   0.4 100.0
*26.0000 +                                                                       0   280   0.0 100.0
*27.0000 +                                                                       0   280   0.0 100.0
*28.0000 +                                                                       0   280   0.0 100.0
*29.0000 +                                                                       0   280   0.0 100.0
*30.0000 +                                                                       0   280   0.0 100.0
*LAST    +                                                                       0   280   0.0 100.0
         +----+----+----+----+----+----+----+----+----+----+----+----+----+
              5    10   15   20   25   30   35   40   45   50   55   60   65
```

Figure 5-2. Maintenance Profile for All Systems

5.3 MAINTENANCE PROFILES: BY SITE.

a. Maintenance data were collected by block release from each of eight sites; these sites are tabulated with abbreviations in table 5-1.

Table 5-1.

Sites From Which Maintenance Data Were Collected

SITE	ABBR
Castle AFB	CASTLE
NORAD/SPACECOM	NORAD
Oklahoma City ALC	OC-ALC
Ogden ALC	OO-ALC
Sacramento ALC	SM-ALC
Tinker AFB	TINKER
Warner-Robbins ALC	WR-ALC
Langley AFB	LANGLEY

In this section, the same data that were presented in section 5.2 are grouped separately by site to allow comparisons between sites. Figure 5-3 is a side-by-side presentation of the maintenance profiles (histograms) for each of the sites. The histograms differ from the one in figure 5-2 chiefly in that the PMPCHNG interval values along the vertical axis decrease (rather than increase) from top to bottom, and the values themselves are the midpoints (instead of the upper limits) of the PMPCHNG intervals. Site abbreviations are listed near the top of the figure.

b. Within the histograms, each asterisk represents 1 release. For some intervals, the number of asterisks exceeds the allowable width of the histogram, so the total frequency for the interval is printed at the end of the asterisk row. For example, in the NORAD histogram there were 17 releases for the interval having a midpoint of 2. The lower and upper limits of that interval are 1.5 and 2.5, respectively. Each interval includes its upper limit (but not its

```
                 ************                                                                      ************
HISTOGRAM OF  *  PMPCHAG   *  (VARIABLE    29).  CASES DIVIDED INTO GROUPS BASED ON VALUES OF  *  NSITE     *  (VARIABLE    23)
                 ************                                                                      ************

             NORAD          WR-ALC        SP-ALC        CASTLE        CO-ALC        OC-ALC        TINKER        LANGLEY
          .............+.............+.............+.............+.............+.............+.............+.............+
 VAR 29
EXCLUDED
 VALUES
                        ****                        ***           **            ***********1C                 **
                 TABULATIONS AND COMPUTATIONS WHICH FOLLOW EXCLUDE VALUES LISTED ABOVE
MIDPOINTS
  26.000)
  25.000)                                                                                                     *
  24.000)
  23.000)
  22.000)               *
  21.000)
  20.000)
  19.000)
  18.000)
  17.000)               *
  16.000)                                                                                                     *
  15.000)
  14.000)*              **
  13.000)                                                                           *
  12.000)*                                                                          *                         *
  11.000)*              *                                                           *                         *
  10.000)*****          *                                                           *             *           *
   9.000)****           *                                                           *             *
   8.000)***                                                          *             *                         *
   7.000)*****          **                                                          *             *
   6.000)***********    **            **                              *                           *           *
   5.000)************   M*****                                                      M             ***         *
   4.000)M********      **            **                              **            *             M****       M****
   3.000)***********13  ***           M***          *                 *             **            ******      *******
   2.000)***********17  *****         *******       M                 M**********   *             *******     ************
   1.000)*********      ************  **            **                ************  *****         ***         *******
   0.000)*******                                                      *******                                   ******
GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH *'S, N'S OTHERWISE
```

	NORAD	WR-ALC	SP-ALC	CASTLE	CO-ALC	OC-ALC	TINKER	LANGLEY
MEAN	4.303	4.511	2.956	1.897	1.786	5.148	3.706	3.649
STD.DEV.	3.020	5.058	1.498	1.415	1.613	4.171	2.190	4.619
R.E.S.D.	3.075	4.653	1.449	1.611	1.344	4.660	2.010	3.619
S. E. M.	0.310	0.810	0.363	0.817	0.273	1.043	0.407	0.681
MAXIMUM	14.217	22.266	6.300	3.471	7.650	12.632	10.350	25.000
MINIMUM	0.060	0.525	1.322	0.734	0.002	0.573	1.077	0.035
SAMPLE SIZE	95	39	17	3	35	16	29	46

ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES
FOR NSITE)

MEAN	3.853
STD.DEV.	3.565
R.E.S.D.	3.237
S. E. M.	0.214
MAXIMUM	25.000
MINIMUM	0.002
SAMPLE SIZE	280

Figure 5-3. Maintenance Profiles for Individual Sites

lower), so for NORAD, 17 releases had PMPCHNG values greater than 1.5 and less than or equal to 2.5 (see for comparison figure 5-4). (Note that BMDP forces a midpoint of 0.000 to mean an interval $\leq$ 0.5 and >- 0.5. Because there are no negative values, this interval is actually $\leq$ 0.5 and > 0 for this data.)

c. Just underneath each histogram are printed several statistics of interest, most notably the mean, the standard deviation (STD.DEV.), and the minimum and maximum PMPCHNG values for the releases of each site. Also listed is the total number of releases (SAMPLE SIZE) included in the histogram for each site. At the bottom of the figure are the same statistics for all sites combined--these agree with the statistics shown at the top of figure 5-2.

d. Figures 5-4 through 5-11 are the site maintenance profiles in the same format as that of figure 5-2. The abbreviation for the site to which the profile applies is printed on the third line at the top of each figure.

5.4 MAINTENANCE PROFILES: BY SOFTWARE SYSTEM TYPE.

a. Seven software system types were represented among the software maintenance data collected across all sites. Table 5-2 is a list of the software system types and their abbreviations/acronyms.

b. Separate maintenance profiles for the software system types are depicted side by side in figure 5-12 in a format identical to that of figure 5-3. System type abbreviations appear near the top of the figure. The maintenance profiles by software system type, in the format of figures 5-2 and 5-4 tnrough 5-11, are presented in figures 5-13 through 5-19, with the system type abbreviation given above each plot.

Table 5-2.

Software System Types for Which Maintenance Data Were Collected

SOFTWARE SYSTEM TYPE	ABBR.
Automatic Test Equipment	ATE
Communications-Electronics	C-E
Electronic Warfare	EW
Operational Flight Program	OFP
Aircrew Training Device	ATD
Simulation	SIM
Utility Support	SUP

```
HISTOGRAM OF VARIABLE    29 PMPCHNG
                                 SYMBOL   COUNT  .   MEAN      ST.DEV.
                     NORAD         A        95       4.303      3.020
                     EACH SYMBOL REPRESENTS            1 OBSERVATIONS
INTERVAL                                                                     FREQUENCY PERCENTAGE
NAME          5    10   15   20   25   30   35   40   45   50   55   60   65  INT. CUM. INT.  CUM.
        +----+----+----+----+----+----+----+----+----+----+----+----+----+
*1.00000 +AAAAAAAAAAA                                                          11   11  11.6  11.6
*2.00000 +AAAAAAAAAAA                                                          11   22  11.6  23.2
*3.00000 +AAAAAAAAAAAAAAAAAAAAAA                                               22   44  23.2  46.3
*4.00000 +AAAAA                                                                 5   49   5.3  51.6
*5.00000 +AAAAAAAAAAA                                                          11   60  11.6  63.2
*6.00000 +AAAAAAAAAAAA                                                         12   72  12.6  75.8
*7.00000 +AAAAAAA                                                               7   79   7.4  83.2
*8.00000 +AA                                                                    2   81   2.1  85.3
*9.00000 +AAAAAA                                                                6   87   6.3  91.6
*10.0000 +AAAA                                                                  4   91   4.2  95.8
*11.0000 +AA                                                                    2   93   2.1  97.9
*12.0000 +                                                                      0   93   0.0  97.9
*13.0000 +A                                                                     1   94   1.1  98.9
*14.0000 +                                                                      0   94   0.0  98.9
*15.0000 +A                                                                     1   95   1.1 100.0
*16.0000 +                                                                      0   95   0.0 100.0
*17.0000 +                                                                      0   95   0.0 100.0
*18.0000 +                                                                      0   95   0.0 100.0
*19.0000 +                                                                      0   95   0.0 100.0
*20.0000 +                                                                      0   95   0.0 100.0
*21.0000 +                                                                      0   95   0.0 100.0
*22.0000 +                                                                      0   95   0.0 100.0
*23.0000 +                                                                      0   95   0.0 100.0
*24.0000 +                                                                      0   95   0.0 100.0
*25.0000 +                                                                      0   95   0.0 100.0
*26.0000 +                                                                      0   95   0.0 100.0
*27.0000 +                                                                      0   95   0.0 100.0
*28.0000 +                                                                      0   95   0.0 100.0
*29.0000 +                                                                      0   95   0.0 100.0
*30.0000 +                                                                      0   95   0.0 100.0
*LAST    +                                                                      0   95   0.0 100.0
        +----+----+----+----+----+----+----+----+----+----+----+----+----+
              5    10   15   20   25   30   35   40   45   50   55   60   65
```

Figure 5-4. Maintenance Profile for NORAD

```
HISTOGRAM OF VARIABLE   29 PMPCHNG
                              SYMBOL  COUNT     MEAN     ST.DEV.
                     WR-ALC     B       39      4.971      5.058
                     EACH SYMBOL REPRESENTS        1 OBSERVATIONS
INTERVAL                                                                 FREQUENCY PERCENTAGE
NAME          5    10   15   20   25   30   35   40   45   50   55   60   65  INT. CUM. INT.  CUM.
        +----+----+----+----+----+----+----+----+----+----+----+----+----+
*1.00000 +BBBBBBBB                                                         8    8  20.5  20.5
*2.00000 +BBBBBBB                                                          7   15  17.9  38.5
*3.00000 +BBB                                                              3   18   7.7  46.2
*4.00000 +BBBB                                                             4   22  10.3  56.4
*5.00000 +BBB                                                              3   25   7.7  64.1
*6.00000 +BBBB                                                             4   29  10.3  74.4
*7.00000 +B                                                                1   30   2.6  76.9
*8.00000 +BB                                                               2   32   5.1  82.1
*9.00000 +                                                                 0   32   0.0  82.1
*10.0000 +B                                                                1   33   2.6  84.6
*11.0000 +B                                                                1   34   2.6  87.2
*12.0000 +B                                                                1   35   2.6  89.7
*13.0000 +                                                                 0   35   0.0  89.7
*14.0000 +                                                                 0   35   0.0  89.7
*15.0000 +BB                                                               2   37   5.1  94.9
*16.0000 +                                                                 0   37   0.0  94.9
*17.0000 +B                                                                1   38   2.6  97.4
*18.0000 +                                                                 0   38   0.0  97.4
*19.0000 +                                                                 0   38   0.0  97.4
*20.0000 +                                                                 0   38   0.0  97.4
*21.0000 +                                                                 0   38   0.0  97.4
*22.0000 +                                                                 0   38   0.0  97.4
*23.0000 +B                                                                1   39   2.6 100.0
*24.0000 +                                                                 0   39   0.0 100.0
*25.0000 +                                                                 0   39   0.0 100.0
*26.0000 +                                                                 0   39   0.0 100.0
*27.0000 +                                                                 0   39   0.0 100.0
*28.0000 +                                                                 0   39   0.0 100.0
*29.0000 +                                                                 0   39   0.0 100.0
*30.0000 +                                                                 0   39   0.0 100.0
*LAST    +                                                                 0   39   0.0 100.0
        +----+----+----+----+----+----+----+----+----+----+----+----+----+
              5    10   15   20   25   30   35   40   45   50   55   60   65
```

Figure 5-5. Maintenance Profile for WR-ALC

```
HISTOGRAM OF VARIABLE    29 PMPCHNG
                                  SYMBOL   COUNT      MEAN      ST.DEV.
                         SM-ALC      C        17       2.956       1.498
                         EACH SYMBOL REPRESENTS         1 OBSERVATIONS
INTERVAL                                                                          FRECUENCY PERCENTAGE
NAME             5    10   15   20   25   30   35   40   45   50   55   60   65   INT. CUM.  INT.  CUM.
                +----+----+----+----+----+----+----+----+----+----+----+----+----+
*1.00000 +                                                                          0    0    0.0    0.0
*2.00000 +CCC                                                                       3    3   17.6   17.6
*3.00000 +CCCCCCCC                                                                  8   11   47.1   64.7
*4.00000 +CC                                                                        2   13   11.8   76.5
*5.00000 +CC                                                                        2   15   11.8   88.2
*6.00000 +                                                                          0   15    0.0   88.2
*7.00000 +CC                                                                        2   17   11.8  100.0
*8.00000 +                                                                          0   17    0.0  100.0
*9.00000 +                                                                          0   17    0.0  100.0
*10.0000 +                                                                          0   17    0.0  100.0
*11.0000 +                                                                          0   17    0.0  100.0
*12.0000 +                                                                          0   17    0.0  100.0
*13.0000 +                                                                          0   17    0.0  100.0
*14.0000 +                                                                          0   17    0.0  100.0
*15.0000 +                                                                          0   17    0.0  100.0
*16.0000 +                                                                          0   17    0.0  100.0
*17.0000 +                                                                          0   17    0.0  100.0
*18.0000 +                                                                          0   17    0.0  100.0
*19.0000 +                                                                          0   17    0.0  100.0
*20.0000 +                                                                          0   17    0.0  100.0
*21.0000 +                                                                          0   17    0.0  100.0
*22.0000 +                                                                          0   17    0.0  100.0
*23.0000 +                                                                          0   17    0.0  100.0
*24.0000 +                                                                          0   17    0.0  100.0
*25.0000 +                                                                          0   17    0.0  100.0
*26.0000 +                                                                          0   17    0.0  100.0
*27.0000 +                                                                          0   17    0.0  100.0
*28.0000 +                                                                          0   17    0.0  100.0
*29.0000 +                                                                          0   17    0.0  100.0
*30.0000 +                                                                          0   17    0.0  100.0
*LAST    +                                                                          0   17    0.0  100.0
                +----+----+----+----+----+----+----+----+----+----+----+----+----+
                 5    10   15   20   25   30   35   40   45   50   55   60   65
```

Figure 5-6. Maintenance Profile for SM-ALC

```
HISTOGRAM OF VARIABLE    29 PMPCHNG
                                  SYMBOL   COUNT       MEAN       ST.DEV.
                         CASTLE      O         3         1.997          1.415
                         EACH SYMBOL REPRESENTS            1 OBSERVATIONS
INTERVAL                                                                      FREQUENCY PERCENTAGE
NAME            5    10    15    20    25    30    35    40    45    50    55    60    65   INT. CUM.  INT.   CUM.
             +----+----+----+----+----+----+----+----+----+----+----+----+----+
*1.00000 +O                                                                    1    1  33.3   33.3
*2.00000 +O                                                                    1    2  33.3   66.7
*3.00000 +                                                                     0    2   0.0   66.7
*4.00000 +O                                                                    1    3  33.3  100.0
*5.00000 +                                                                     0    3   0.0  100.0
*6.00000 +                                                                     0    3   0.0  100.0
*7.00000 +                                                                     0    3   0.0  100.0
*8.00000 +                                                                     0    3   0.0  100.0
*9.00000 +                                                                     0    3   0.0  100.0
*10.0000 +                                                                     0    3   0.0  100.0
*11.0000 +                                                                     0    3   0.0  100.0
*12.0000 +                                                                     0    3   0.0  100.0
*13.0000 +                                                                     0    3   0.0  100.0
*14.0000 +                                                                     0    3   0.0  100.0
*15.0000 +                                                                     0    3   0.0  100.0
*16.0000 +                                                                     0    3   0.0  100.0
*17.0000 +                                                                     0    3   0.0  100.0
*18.0000 +                                                                     0    3   0.0  100.0
*19.0000 +                                                                     0    3   0.0  100.0
*20.0000 +                                                                     0    3   0.0  100.0
*21.0000 +                                                                     0    3   0.0  100.0
*22.0000 +                                                                     0    3   0.0  100.0
*23.0000 +                                                                     0    3   0.0  100.0
*24.0000 +                                                                     0    3   0.0  100.0
*25.0000 +                                                                     0    3   0.0  100.0
*26.0000 +                                                                     0    3   0.0  100.0
*27.0000 +                                                                     0    3   0.0  100.0
*28.0000 +                                                                     0    3   0.0  100.0
*29.0000 +                                                                     0    3   0.0  100.0
*30.0000 +                                                                     0    3   0.0  100.0
*LAST    +                                                                     0    3   0.0  100.0
             +----+----+----+----+----+----+----+----+----+----+----+----+----+
                5    10    15    20    25    30    35    40    45    50    55    60    65
```

Figure 5-7. Maintenance Profile for CASTLE AFB

```
HISTOGRAM OF VARIABLE    29 PMPCHNG
                                  SYMBOL   COUNT      MEAN      ST.DEV.
                         OO-ALC      E        35       1.786        1.613
                         EACH SYMBOL REPRESENTS          1 OBSERVATIONS
INTERVAL                                                                        FREQUENCY PERCENTAGE
NAME           5    10    15    20    25    30    35    40    45    50    55    60    65  INT. CUM. INT.  CUM.
          +----+----+----+----+----+----+----+----+----+----+----+----+----+
*1.00000  +EEEEEEEE                                                                   8    8  22.9   22.9
*2.00000  +EEEEEEEEEEEEEEEEE                                                         17   25  48.6   71.4
*3.00000  +EEEEEE                                                                     6   31  17.1   88.6
*4.00000  +E                                                                          1   32   2.9   91.4
*5.00000  +E                                                                          1   33   2.9   94.3
*6.00000  +                                                                           0   33   0.0   94.3
*7.00000  +E                                                                          1   34   2.9   97.1
*8.00000  +E                                                                          1   35   2.9  100.0
*9.00000  +                                                                           0   35   0.0  100.0
*10.0000  +                                                                           0   35   0.0  100.0
*11.0000  +                                                                           0   35   0.0  100.0
*12.0000  +                                                                           0   35   0.0  100.0
*13.0000  +                                                                           0   35   0.0  100.0
*14.0000  +                                                                           0   35   0.0  100.0
*15.0000  +                                                                           0   35   0.0  100.0
*16.0000  +                                                                           0   35   0.0  100.0
*17.0000  +                                                                           0   35   0.0  100.0
*18.0000  +                                                                           0   35   0.0  100.0
*19.0000  +                                                                           0   35   0.0  100.0
*20.0000  +                                                                           0   35   0.0  100.0
*21.0000  +                                                                           0   35   0.0  100.0
*22.0000  +                                                                           0   35   0.0  100.0
*23.0000  +                                                                           0   35   0.0  100.0
*24.0000  +                                                                           0   35   0.0  100.0
*25.0000  +                                                                           0   35   0.0  100.0
*26.0000  +                                                                           0   35   0.0  100.0
*27.0000  +                                                                           0   35   0.0  100.0
*28.0000  +                                                                           0   35   0.0  100.0
*29.0000  +                                                                           0   35   0.0  100.0
*30.0000  +                                                                           0   35   0.0  100.0
*LAST     +                                                                           0   35   0.0  100.0
          +----+----+----+----+----+----+----+----+----+----+----+----+----+
               5    10    15    20    25    30    35    40    45    50    55    60    65
```

Figure 5-8. Maintenance Profile for OO-ALC

```
HISTOGRAM OF VARIABLE   29 PMPCHNG
                              SYMBOL   COUNT      MEAN      ST.DEV.
                      OC-ALC       F        16       5.148        4.171
                      EACH SYMBOL REPRESENTS          1 OBSERVATIONS
INTERVAL                                                                      FREQUENCY PERCENTAGE
NAME            5    10    15    20    25    30    35    40    45    50    55    60    65   INT. CUM.  INT.   CUM.
         +----+----+----+----+----+----+----+----+----+----+----+----+----+
*1.00000 +F                                                                      1    1    6.3    6.3
*2.00000 +FFFFF                                                                  5    6   31.3   37.5
*3.00000 +F                                                                      1    7    6.3   43.8
*4.00000 +FF                                                                     2    9   12.5   56.3
*5.00000 +F                                                                      1   10    6.3   62.5
*6.00000 +                                                                       0   10    0.0   62.5
*7.00000 +F                                                                      1   11    6.3   68.8
*8.00000 +                                                                       0   11    0.0   68.8
*9.00000 +F                                                                      1   12    6.3   75.0
*10.0000 +F                                                                      1   13    6.3   81.3
*11.0000 +F                                                                      1   14    6.3   87.5
*12.0000 +F                                                                      1   15    6.3   93.8
*13.0000 +F                                                                      1   16    6.3  100.0
*14.0000 +                                                                       0   16    0.0  100.0
*15.0000 +                                                                       0   16    0.0  100.0
*16.0000 +                                                                       0   16    0.0  100.0
*17.0000 +                                                                       0   16    0.0  100.0
*18.0000 +                                                                       0   16    0.0  100.0
*19.0000 +                                                                       0   16    0.0  100.0
*20.0000 +                                                                       0   16    0.0  100.0
*21.0000 +                                                                       0   16    0.0  100.0
*22.0000 +                                                                       0   16    0.0  100.0
*23.0000 +                                                                       0   16    0.0  100.0
*24.0000 +                                                                       0   16    0.0  100.0
*25.0000 +                                                                       0   16    0.0  100.0
*26.0000 +                                                                       0   16    0.0  100.0
*27.0000 +                                                                       0   16    0.0  100.0
*28.0000 +                                                                       0   16    0.0  100.0
*29.0000 +                                                                       0   16    0.0  100.0
*30.0000 +                                                                       0   16    0.0  100.0
*LAST    +                                                                       0   16    0.0  100.0
         +----+----+----+----+----+----+----+----+----+----+----+----+----+
                5    10    15    20    25    30    35    40    45    50    55    60    65
```

Figure 5-9. Maintenance Profile for OC-ALC

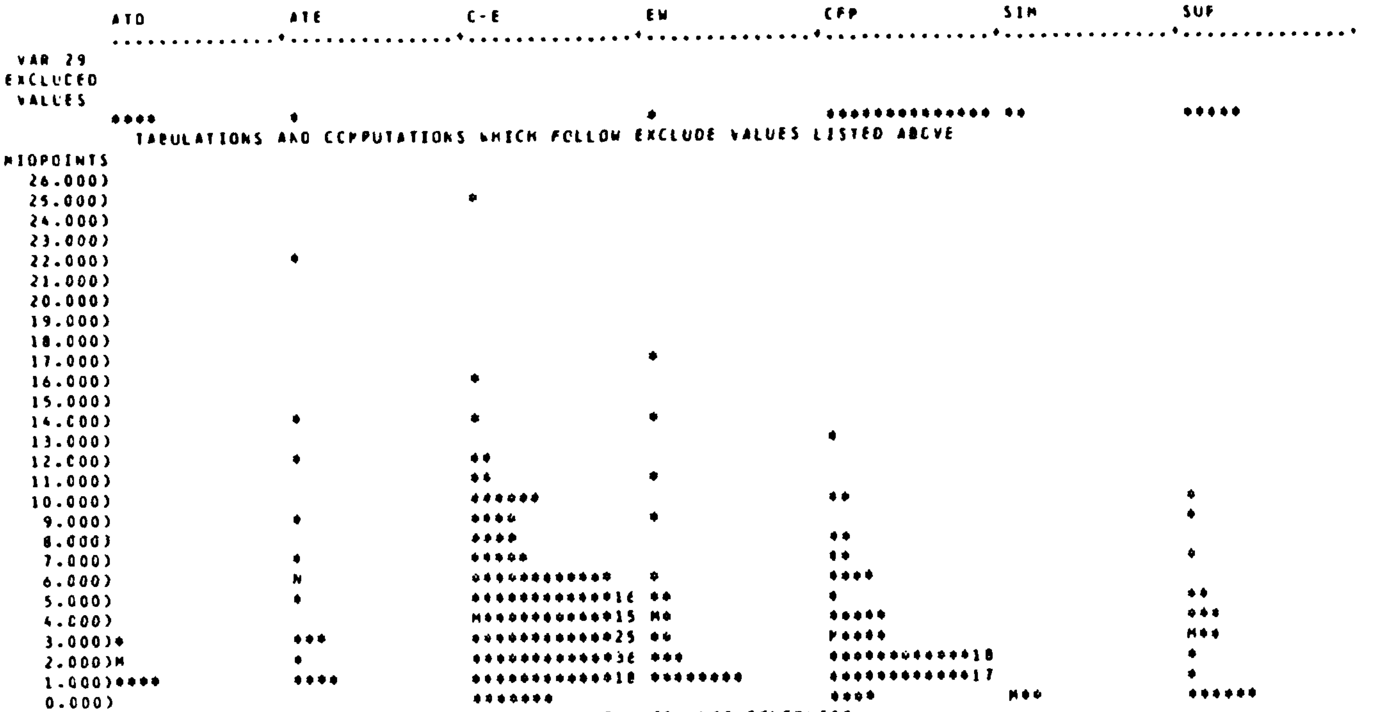
```
HISTOGRAM OF VARIABLE   29 PMPCHNG
                                  SYMBOL   COUNT      MEAN     ST.DEV.
                         TINKER      G        29       3.706      2.190
                         EACH SYMBOL REPRESENTS          1 OBSERVATIONS
INTERVAL                                                                               FREQUENCY PERCENTAGE
NAME            5    10    15    20    25    30    35    40    45    50    55    60    65  INT. CUM.  INT.  CUM.
              +----+----+----+----+----+----+----+----+----+----+----+----+----+
*1.00000 +                                                                              0    0   0.0    0.0
*2.00000 +GGGGGG                                                                        6    6  20.7   20.7
*3.00000 +GGGGGG                                                                        6   12  20.7   41.4
*4.00000 +GGGGGGGG                                                                      8   20  27.6   69.0
*5.00000 +GGG                                                                           3   23  10.3   79.3
*6.00000 +GGG                                                                           3   26  10.3   89.7
*7.00000 +G                                                                             1   27   3.4   93.1
*8.00000 +                                                                              0   27   0.0   93.1
*9.00000 +                                                                              0   27   0.0   93.1
*10.0000 +G                                                                             1   28   3.4   96.6
*11.0000 +G                                                                             1   29   3.4  100.0
*12.0000 +                                                                              0   29   0.0  100.0
*13.0000 +                                                                              0   29   0.0  100.0
*14.0000 +                                                                              0   29   0.0  100.0
*15.0000 +                                                                              0   29   0.0  100.0
*16.0000 +                                                                              0   29   0.0  100.0
*17.0000 +                                                                              0   29   0.0  100.0
*18.0000 +                                                                              0   29   0.0  100.0
*19.0000 +                                                                              0   29   0.0  100.0
*20.0000 +                                                                              0   29   0.0  100.0
*21.0000 +                                                                              0   29   0.0  100.0
*22.0000 +                                                                              0   29   0.0  100.0
*23.0000 +                                                                              0   29   0.0  100.0
*24.0000 +                                                                              0   29   0.0  100.0
*25.0000 +                                                                              0   29   0.0  100.0
*26.0000 +                                                                              0   29   0.0  100.0
*27.0000 +                                                                              0   29   0.0  100.0
*28.0000 +                                                                              0   29   0.0  100.0
*29.0000 +                                                                              0   29   0.0  100.0
*30.0000 +                                                                              0   29   0.0  100.0
*LAST    +                                                                              0   29   0.0  100.0
              +----+----+----+----+----+----+----+----+----+----+----+----+----+
                5    10    15    20    25    30    35    40    45    50    55    60    65
```

Figure 5-10. Maintenance Profile for Tinker AFB

```
HISTOGRAM OF VARIABLE    29 PMPCHNG
                                    SYMBOL   COUNT      MEAN      ST.DEV.
                        LANGLEY       H        46       3.649       4.619
                        EACH SYMBOL REPRESENTS            1 OBSERVATIONS
INTERVAL                                                                    FREQUENCY  PERCENTAGE
NAME            5    10   15   20   25   30   35   40   45   50   55   60   65   INT. CUM.  INT.   CUM.
          +----+----+----+----+----+----+----+----+----+----+----+----+----+
*1.00000  +HHHHHHH                                                            7    7   15.2   15.2
*2.00000  +HHHHHHHHHHHHHHH                                                   15   22   32.6   47.8
*3.00000  +HHHHHHHHH                                                          9   31   19.6   67.4
*4.00000  +HHHH                                                               4   35    8.7   76.1
*5.00000  +HHHH                                                               4   39    8.7   84.8
*6.00000  +H                                                                  1   40    2.2   87.0
*7.00000  +                                                                   0   40    0.0   87.0
*8.00000  +H                                                                  1   41    2.2   89.1
*9.00000  +                                                                   0   41    0.0   89.1
*10.0000  +H                                                                  1   42    2.2   91.3
*11.0000  +H                                                                  1   43    2.2   93.5
*12.0000  +                                                                   0   43    0.0   93.5
*13.0000  +H                                                                  1   44    2.2   95.7
*14.0000  +                                                                   0   44    0.0   95.7
*15.0000  +                                                                   0   44    0.0   95.7
*16.0000  +H                                                                  1   45    2.2   97.8
*17.0000  +                                                                   0   45    0.0   97.8
*18.0000  +                                                                   0   45    0.0   97.8
*19.0000  +                                                                   0   45    0.0   97.8
*20.0000  +                                                                   0   45    0.0   97.8
*21.0000  +                                                                   0   45    0.0   97.8
*22.0000  +                                                                   0   45    0.0   97.8
*23.0000  +                                                                   0   45    0.0   97.8
*24.0000  +                                                                   0   45    0.0   97.8
*25.0000  +H                                                                  1   46    2.2  100.0
*26.0000  +                                                                   0   46    0.0  100.0
*27.0000  +                                                                   0   46    0.0  100.0
*28.0000  +                                                                   0   46    0.0  100.0
*29.0000  +                                                                   0   46    0.0  100.0
*30.0000  +                                                                   0   46    0.0  100.0
*LAST     +                                                                   0   46    0.0  100.0
          +----+----+----+----+----+----+----+----+----+----+----+----+----+
                5    10   15   20   25   30   35   40   45   50   55   60   65

NUMBER OF INTEGER WORDS OF STORAGE USED IN PRECEDING     PROBLEM     1538
CPU TIME USED       10.770 SECONDS
```

Figure 5-11. Maintenance Profile for Langley AFB

HISTOGRAM OF * MMPCHNG * (VARIABLE 29). CASES DIVIDED INTO GROUPS BASED ON VALUES OF * NSWTYPE * (VARIABLE 24)



GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH *'S, N'S OTHERWISE

	ATD	ATE	C-E	EW	CFP	SIM	SUF
MEAN	1.786	5.968	4.118	4.415	3.067	0.102	3.248
STD.DEV.	1.008	6.452	3.410	4.572	2.720	0.111	3.101
R.E.S.D.	1.094	6.513	3.067	4.363	2.581	0.121	3.118
S. E. M.	0.412	1.724	0.274	0.975	0.348	0.064	0.711
MAXIMUM	3.471	22.286	25.000	16.514	12.632	0.221	10.350
MINIMUM	0.734	0.525	0.060	0.808	0.064	0.002	0.035
SAMPLE SIZE	6	14	155	22	61	3	19

ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES
FOR NSWTYPE)

MEAN	3.853
STD.DEV.	3.565
R.E.S.D.	3.237
S. E. M.	0.214
MAXIMUM	25.000
MINIMUM	0.002
SAMPLE SIZE	280

Figure 5-12. Maintenance Profiles for Software System Types

```
HISTOGRAM OF VARIABLE    29 PMPCHNG
                                   SYMBOL   COUNT      MEAN      ST.DEV.
                         ATD          A        6        1.786       1.008
                         EACH SYMBOL REPRESENTS          1 OBSERVATIONS
INTERVAL                                                                            FREQUENCY PERCENTAGE
NAME          5    10   15   20   25   30   35   40   45   50   55   60   65   INT. CUM.  INT.   CUM.
             +----+----+----+----+----+----+----+----+----+----+----+----+----+
*1.00000     +A                                                                    1    1   16.7   16.7
*2.00000     +AAA                                                                  3    4   50.0   66.7
*3.00000     +A                                                                    1    5   16.7   83.3
*4.00000     +A                                                                    1    6   16.7  100.0
*5.00000     +                                                                     0    6    0.0  100.0
*6.00000     +                                                                     0    6    0.0  100.0
*7.00000     +                                                                     0    6    0.0  100.0
*8.00000     +                                                                     0    6    0.0  100.0
*9.00000     +                                                                     0    6    0.0  100.0
*10.0000     +                                                                     0    6    0.0  100.0
*11.0000     +                                                                     0    6    0.0  100.0
*12.0000     +                                                                     0    6    0.0  100.0
*13.0000     +                                                                     0    6    0.0  100.0
*14.0000     +                                                                     0    6    0.0  100.0
*15.0000     +                                                                     0    6    0.0  100.0
*16.0000     +                                                                     0    6    0.0  100.0
*17.0000     +                                                                     0    6    0.0  100.0
*18.0000     +                                                                     0    6    0.0  100.0
*19.0000     +                                                                     0    6    0.0  100.0
*20.0000     +                                                                     0    6    0.0  100.0
*21.0000     +                                                                     0    6    0.0  100.0
*22.0000     +                                                                     0    6    0.0  100.0
*23.0000     +                                                                     0    6    0.0  100.0
*24.0000     +                                                                     0    6    0.0  100.0
*25.0000     +                                                                     0    6    0.0  100.0
*26.0000     +                                                                     0    6    0.0  100.0
*27.0000     +                                                                     0    6    0.0  100.0
*28.0000     +                                                                     0    6    0.0  100.0
*29.0000     +                                                                     0    6    0.0  100.0
*30.0000     +                                                                     0    6    0.0  100.0
*LAST        +                                                                     0    6    0.0  100.0
             +----+----+----+----+----+----+----+----+----+----+----+----+----+
              5    10   15   20   25   30   35   40   45   50   55   60   65
```

Figure 5-13. Maintenance Profile for ATD

```
HISTOGRAM OF VARIABLE    29 PMPCHNG
                                   SYMBOL   COUNT      MEAN      ST.DEV.
                         ATE            B      14      5.968       6.452
                         EACH SYMBCL REPRESENTS          1 OBSERVATIONS
INTERVAL                                                                      FREQUENCY PERCENTAGE
NAME              5    10   15   20   25   30   35   40   45   50   55   60   65  INT. CUM. INT.  CUM.
           +----+----+----+----+----+----+----+----+----+----+----+----+----+
*1.00000   +BBBB                                                                 4    4   26.6  28.6
*2.00000   +B                                                                    1    5    7.1  35.7
*3.00000   +BB                                                                   2    7   14.3  50.0
*4.00000   +B                                                                    1    8    7.1  57.1
*5.00000   +                                                                     0    8    0.0  57.1
*6.00000   +B                                                                    1    9    7.1  64.3
*7.00000   +B                                                                    1   10    7.1  71.4
*8.00000   +                                                                     0   10    0.0  71.4
*9.00000   +                                                                     0   10    0.0  71.4
*10.0000   +B                                                                    1   11    7.1  78.6
*11.0000   +                                                                     0   11    0.0  78.6
*12.0000   +B                                                                    1   12    7.1  85.7
*13.0000   +                                                                     0   12    0.0  85.7
*14.0000   +                                                                     0   12    0.0  85.7
*15.0000   +B                                                                    1   13    7.1  92.9
*16.0000   +                                                                     0   13    0.0  92.9
*17.0000   +                                                                     0   13    0.0  92.9
*18.0000   +                                                                     0   13    0.0  92.9
*19.0000   +                                                                     0   13    0.0  92.9
*20.0000   +                                                                     0   13    0.0  92.9
*21.0000   +                                                                     0   13    0.0  92.9
*22.0000   +                                                                     0   13    0.0  92.9
*23.0000   +B                                                                    1   14    7.1 100.0
*24.0000   +                                                                     0   14    0.0 100.0
*25.0000   +                                                                     0   14    0.0 100.0
*26.0000   +                                                                     0   14    0.0 100.0
*27.0000   +                                                                     0   14    0.0 100.0
*28.0000   +                                                                     0   14    0.0 100.0
*29.0000   +                                                                     0   14    0.0 100.0
*30.0000   +                                                                     0   14    0.0 100.0
*LAST      +                                                                     0   14    0.0 100.0
           +----+----+----+----+----+----+----+----+----+----+----+----+----+
                  5    10   15   20   25   30   35   40   45   50   55   60   65
```

Figure 5-14. Maintenance Profile for ATE

```
HISTOGRAM OF VARIABLE   29 PMPCHNG
                                  SYMBOL   COUNT       MEAN      ST.DEV.
                        C-E          C      155        4.118       3.410
                        EACH SYMBOL REPRESENTS           1 OBSERVATIONS
INTERVAL                                                                                FREQUENCY PERCENTAGE
NAME             5   10   15   20   25   30   35   40   45   50   55   60   65   INT.  CUM.  INT.   CUM.
               +----+----+----+----+----+----+----+----+----+----+----+----+----+
*1.00000 +CCCCCCCCCCCC                                                              12    12   7.7    7.7
*2.00000 +CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC                                           31    43  20.0   27.7
*3.00000 +CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC                                      36    79  23.2   51.0
*4.00000 +CCCCCCCCCCCCCC                                                            14    93   9.0   60.0
*5.00000 +CCCCCCCCCCCCCCCCCC                                                        18   111  11.6   71.6
*6.00000 +CCCCCCCCCCCCCCC                                                           15   126   9.7   81.3
*7.00000 +CCCCCCC                                                                    7   133   4.5   85.8
*8.00000 +CCC                                                                        3   136   1.9   87.7
*9.00000 +CCCCCC                                                                     6   142   3.9   91.6
*10.0000 +CCCCC                                                                      5   147   3.2   94.8
*11.0000 +CCC                                                                        3   150   1.9   96.8
*12.0000 +                                                                           0   150   0.0   96.8
*13.0000 +CC                                                                         2   152   1.3   98.1
*14.0000 +                                                                           0   152   0.0   98.1
*15.0000 +C                                                                          1   153   0.6   98.7
*16.0000 +C                                                                          1   154   0.6   99.4
*17.0000 +                                                                           0   154   0.0   99.4
*18.0000 +                                                                           0   154   0.0   99.4
*19.0000 +                                                                           0   154   0.0   99.4
*20.0000 +                                                                           0   154   0.0   99.4
*21.0000 +                                                                           0   154   0.0   99.4
*22.0000 +                                                                           0   154   0.0   99.4
*23.0000 +                                                                           0   154   0.0   99.4
*24.0000 +                                                                           0   154   0.0   99.4
*25.0000 +C                                                                          1   155   0.6  100.0
*26.0000 +                                                                           0   155   0.0  100.0
*27.0000 +                                                                           0   155   0.0  100.0
*28.0000 +                                                                           0   155   0.0  100.0
*29.0000 +                                                                           0   155   0.0  100.0
*30.0000 +                                                                           0   155   0.0  100.0
*LAST    +                                                                           0   155   0.0  100.0
               +----+----+----+----+----+----+----+----+----+----+----+----+----+
                 5   10   15   20   25   30   35   40   45   50   55   60   65
```

Figure 5-15. Maintenance Profile for C-E

```
HISTOGRAM OF VARIABLE   29 PMPCHNG
                                 SYMBOL   COUNT      MEAN      ST.DEV.
                         EW        D        22        4.415       4.572
                         EACH SYMBOL REPRESENTS        1 OBSERVATIONS
INTERVAL                                                                      FREQUENCY PERCENTAGE
NAME            5    10   15   20   25   30   35   40   45   50   55   60   65   INT. CUM.  INT.   CUM.
          +----+----+----+----+----+----+----+----+----+----+----+----+----+
*1.00000 +DDDDD                                                                   5    5   22.7   22.7
*2.00000 +DDDD                                                                    4    9   18.2   40.9
*3.00000 +DD                                                                      2   11    9.1   50.0
*4.00000 +DDDD                                                                    4   15   18.2   68.2
*5.00000 +D                                                                       1   16    4.5   72.7
*6.00000 +D                                                                       1   17    4.5   77.3
*7.00000 +D                                                                       1   18    4.5   81.8
*8.00000 +                                                                        0   18    0.0   81.8
*9.00000 +                                                                        0   18    0.0   81.8
*10.0000 +D                                                                       1   19    4.5   86.4
*11.0000 +                                                                        0   19    0.0   86.4
*12.0000 +D                                                                       1   20    4.5   90.9
*13.0000 +                                                                        0   20    0.0   90.9
*14.0000 +                                                                        0   20    0.0   90.9
*15.0000 +D                                                                       1   21    4.5   95.5
*16.0000 +                                                                        0   21    0.0   95.5
*17.0000 +D                                                                       1   22    4.5  100.0
*18.0000 +                                                                        0   22    0.0  100.0
*19.0000 +                                                                        0   22    0.0  100.0
*20.0000 +                                                                        0   22    0.0  100.0
*21.0000 +                                                                        0   22    0.0  100.0
*22.0000 +                                                                        0   22    0.0  100.0
*23.0000 +                                                                        0   22    0.0  100.0
*24.0000 +                                                                        0   22    0.0  100.0
*25.0000 +                                                                        0   22    0.0  100.0
*26.0000 +                                                                        0   22    0.0  100.0
*27.0000 +                                                                        0   22    0.0  100.0
*28.0000 +                                                                        0   22    0.0  100.0
*29.0000 +                                                                        0   22    0.0  100.0
*30.0000 +                                                                        0   22    0.0  100.0
*LAST    +                                                                        0   22    0.0  100.0
          +----+----+----+----+----+----+----+----+----+----+----+----+----+
                5    10   15   20   25   30   35   40   45   50   55   60   65
```

Figure 5-16. Maintenance Profile for EW

```
HISTOGRAM OF VARIABLE    29 PMFCHNG
                                  SYMBOL   COUNT      MEAN      ST.DEV.
                         OFP        E        61       3.067       2.720
                         EACH SYMBOL REPRESENTS         1 OBSERVATIONS
INTERVAL                                                                      FREQUENCY  PERCENTAGE
NAME           5    10   15   20   25   30   35   40   45   50   55   60   65  INT. CUM.  INT.  CUM.
          +----+----+----+----+----+----+----+----+----+----+----+----+----+
*1.00000  +EEEEE                                                                5    5    8.2    8.2
*2.00000  +EEEEEEEEEEEEEEEEEEEEEEEE                                            24   29   39.3   47.5
*3.00000  +EEEEEEEEEEEEE                                                       13   42   21.3   68.9
*4.00000  +EEEE                                                                 4   46    6.6   75.4
*5.00000  +EEE                                                                  3   49    4.9   80.3
*6.00000  +EE                                                                   2   51    3.3   83.6
*7.00000  +EEE                                                                  3   54    4.9   88.5
*8.00000  +EEE                                                                  3   57    4.9   93.4
*9.00000  +E                                                                    1   58    1.6   95.1
*10.0000  +                                                                     0   58    0.0   95.1
*11.0000  +EE                                                                   2   60    3.3   98.4
*12.0000  +                                                                     0   60    0.0   98.4
*13.0000  +E                                                                    1   61    1.6  100.0
*14.0000  +                                                                     0   61    0.0  100.0
*15.0000  +                                                                     0   61    0.0  100.0
*16.0000  +                                                                     0   61    0.0  100.0
*17.0000  +                                                                     0   61    0.0  100.0
*18.0000  +                                                                     0   61    0.0  100.0
*19.0000  +                                                                     0   61    0.0  100.0
*20.0000  +                                                                     0   61    0.0  100.0
*21.0000  +                                                                     0   61    0.0  100.0
*22.0000  +                                                                     0   61    0.0  100.0
*23.0000  +                                                                     0   61    0.0  100.0
*24.0000  +                                                                     0   61    0.0  100.0
*25.0000  +                                                                     0   61    0.0  100.0
*26.0000  +                                                                     0   61    0.0  100.0
*27.0000  +                                                                     0   61    0.0  100.0
*28.0000  +                                                                     0   61    0.0  100.0
*29.0000  +                                                                     0   61    0.0  100.0
*30.0000  +                                                                     0   61    0.0  100.0
*LAST     +                                                                     0   61    0.0  100.0
          +----+----+----+----+----+----+----+----+----+----+----+----+----+
               5    10   15   20   25   30   35   40   45   50   55   60   65
```

Figure 5-17. Maintenance Profile for OFP

```
HISTOGRAM OF VARIABLE   29 PMPCHNG
                                  SYMBOL  COUNT     MEAN     ST.DEV.
                        SIM          F      3       0.102      0.111
                        EACH SYMBOL REPRESENTS        1 OBSERVATIONS
INTERVAL                                                                 FREQUENCY PERCENTAGE
NAME           5   10   15   20   25   30   35   40   45   50   55   60   65  INT. CUM. INT.  CUM.
             +----+----+----+----+----+----+----+----+----+----+----+----+----+
*1.00000 +FFF                                                                  3    3 100.0 100.0
*2.00000 +                                                                     0    3   0.0 100.0
*3.00000 +                                                                     0    3   0.0 100.0
*4.00000 +                                                                     0    3   0.0 100.0
*5.00000 +                                                                     0    3   0.0 100.0
*6.00000 +                                                                     0    3   0.0 100.0
*7.00000 +                                                                     0    3   0.0 100.0
*8.00000 +                                                                     0    3   0.0 100.0
*9.00000 +                                                                     0    3   0.0 100.0
*10.0000 +                                                                     0    3   0.0 100.0
*11.0000 +                                                                     0    3   0.0 100.0
*12.0000 +                                                                     0    3   0.0 100.0
*13.0000 +                                                                     0    3   0.0 100.0
*14.0000 +                                                                     0    3   0.0 100.0
*15.0000 +                                                                     0    3   0.0 100.0
*16.0000 +                                                                     0    3   0.0 100.0
*17.0000 +                                                                     0    3   0.0 100.0
*18.0000 +                                                                     0    3   0.0 100.0
*19.0000 +                                                                     0    3   0.0 100.0
*20.0000 +                                                                     0    3   0.0 100.0
*21.0000 +                                                                     0    3   0.0 100.0
*22.0000 +                                                                     0    3   0.0 100.0
*23.0000 +                                                                     0    3   0.0 100.0
*24.0000 +                                                                     0    3   0.0 100.0
*25.0000 +                                                                     0    3   0.0 100.0
*26.0000 +                                                                     0    3   0.0 100.0
*27.0000 +                                                                     0    3   0.0 100.0
*28.0000 +                                                                     0    3   0.0 100.0
*29.0000 +                                                                     0    3   0.0 100.0
*30.0000 +                                                                     0    3   0.0 100.0
*LAST    +                                                                     0    3   0.0 100.0
             +----+----+----+----+----+----+----+----+----+----+----+----+----+
               5   10   15   20   25   30   35   40   45   50   55   60   65
```

Figure 5-18. Maintenance Profile for SIM

```
HISTOGRAM OF VARIABLE    29 PPFCHNG'
                                SYMBOL   COUNT      MEAN      ST.DEV.
                      SUP         G        19       3.248       3.101
                      EACH SYMBOL REPRESENTS           1 OBSERVATIONS
INTERVAL                                                                        FRECUENCY  PERCENTAGE
NAME             5    10   15   20   25   30   35   40   45   50   55   60   65   INT. CUM.  INT.  CUM.
         +----+----+----+----+----+----+----+----+----+----+----+----+----+
*1.00000 +GGGGGG                                                                 6    6   31.6   31.6
*2.00000 +GG                                                                     2    8   10.5   42.1
*3.00000 +G                                                                      1    9    5.3   47.4
*4.00000 +GGG                                                                    3   12   15.8   63.2
*5.00000 +GGG                                                                    3   15   15.8   78.9
*6.00000 +G                                                                      1   16    5.3   84.2
*7.00000 +G                                                                      1   17    5.3   89.5
*8.00000 +                                                                       0   17    0.0   89.5
*9.00000 +                                                                       0   17    0.0   89.5
*10.0000 +G                                                                      1   18    5.3   94.7
*11.0000 +G                                                                      1   19    5.3  100.0
*12.0000 +                                                                       0   19    0.0  100.0
*13.0000 +                                                                       0   19    0.0  100.0
*14.0000 +                                                                       0   19    0.0  100.0
*15.0000 +                                                                       0   19    0.0  100.0
*16.0000 +                                                                       0   19    0.0  100.0
*17.0000 +                                                                       0   19    0.0  100.0
*18.0000 +                                                                       0   19    0.0  100.0
*19.0000 +                                                                       0   19    0.0  100.0
*20.0000 +                                                                       0   19    0.0  100.0
*21.0000 +                                                                       0   19    0.0  100.0
*22.0000 +                                                                       0   19    0.0  100.0
*23.0000 +                                                                       0   19    0.0  100.0
*24.0000 +                                                                       0   19    0.0  100.0
*25.0000 +                                                                       0   19    0.0  100.0
*26.0000 +                                                                       0   19    0.0  100.0
*27.0000 +                                                                       0   19    0.0  100.0
*28.0000 +                                                                       0   19    0.0  100.0
*29.0000 +                                                                       0   19    0.0  100.0
*30.0000 +                                                                       0   19    0.0  100.0
*LAST    +                                                                       0   19    0.0  100.0
         +----+----+----+----+----+----+----+----+----+----+----+----+----+
                 5    10   15   20   25   30   35   40   45   50   55   60   65
```

Figure 5-19. Maintenance Profile for SUP

VI. Methodology Review

SECTION VI

METHODOLOGY REVIEW

6.1 BACKGROUND.

a. The proposed methodology for risk assessment of software supportability was first presented in the reference 8.3 report. An update of the methodology illustrating the hypothetical generation and use of baseline historical maintenance profiles is presented in reference 8.9. The methodology is referred to as the Risk Assessment Methodology for Software Supportability (RAMSS). Further development of the concepts, primarily in the form of an extended example is presented in reference 8.6. A summary of the impact of the data collected upon the RAMSS is presented in table 4-1 of this report.

b. For the purpose of completeness, a brief review of the RAMSS major features, the evaluation procedure, and the extended example from reference 8.6 is presented in this section. The analysis results from section IV and use of actual historical maintenance profiles from section V would provide only a greater level of detail and accuracy. Hence, the original hypothesized data from reference 8.6 is retained as part of the extended example.

6.2 MAJOR FEATURES.

The major features of the RAMSS framework include:

(1) A baseline software supportability profile of expected software maintenance actions is proposed. This baseline would evolve as necessary into an agreement between the using and supporting organizations. It would be derived using a historical maintenance data base as a guideline.

(2) Software supportability evaluation metrics are derived from characteristics of the software products, software support environment, and the software life cycle process management. The evaluation is conducted relative to the baseline software supportability profile.

(3) Estimated software supportability risk is computed from the software supportability evaluation metrics using a simple conversion function. Iteration with feature 2 above will eventually result in an estimated risk which is acceptable (i.e., the baseline acceptable risk). The conversion function (or perhaps a more empirical function) must be validated using the historical maintenance data. More valid methods are presented in section IV but do not influence the general use of such an acceptable risk value.

(4) Software supportability risk is evaluated for consequences and alternative choices by direct comparison of the baseline acceptable risk, the evaluated risk, the baseline support profiles, and the evaluated software supportability characteristics.

(5) Elements of the framework can be applied throughout the software development and support life cycle phases whenever software evaluations can be conducted.

(6) Elements of the framework are applicable to any software quality evaluation where the quality affects the operation or support of a system. As an example, risk assessment of software reliability could use a similar framework with a baseline of operational requirements against which software reliability is evaluated.

6.3 EVALUATION PROCEDURES.

6.3.1 Life Cycle Phases. Evaluation of software supportability is a life cycle process. There are key points (such as milestones 1, 2, 3, critical design review, IOC, PMRT) throughout a software system's life cycle where application of a RAMSS (or some part of it) would be beneficial. Benefits which might occur include: early planning and trade-off studies for software support facility resource requirements; early view of potential software support management problems; early visibility of user requirements for expected software support actions; capability to trace software supportability risk profile (i.e., measures of risk) throughout the life cycle; early view of expected software supportability risk drivers; and the actual assessment of the risk to user and supporter which must be accepted before support of the software can be assumed.

6.3.2 Steps of Evaluation Procedure.

a. The basic steps of a procedure to control the evaluation process include: planning; evaluation; analysis; and reporting. Typical actions for each of these steps are presented in figure 6-1.

b. From the perspective of a RAMSS, the primary function in the planning phase is to establish an appropriate baseline profile of expected maintenance actions. Because of the level at which the evaluation is being conducted, it may not be necessary to consider a full baseline profile. A more complete methodology should establish guidelines for collecting and tailoring the baseline profile data to requirements appropriate for the desired level of evaluation. Tailoring the data might involve averaging the data into a single baseline value with a specified range of variance. This would greatly simplify the effort of the evaluator, but would also add uncertainty in the accuracy of the evaluation metrics.

PLAN EVALUATION

- ESTABLISH BASELINE SS PROFILE
- TAILOR PROFILE TO LEVEL OF EVALUATION
- ESTABLISH EVALUATION STRUCTURE FOR
  - SOFTWARE PRODUCTS
  - SOFTWARE SUPPORT FACILITY
  - SOFTWARE SUPPORT MANAGEMENT

▼

CONDUCT EVALUATION

- CALIBRATE EVALUATION QUESTIONNAIRES AND EVALUATORS. EXPLAIN BASELINE SS PROFILE AND RELATIONSHIP TO EVALUATION METRICS AND RISK MEASURES
- COMPLETE EVALUATION AT LEVEL DESIGNATED BY PLAN
  - EVALUATOR INFORMATION AND COMMENTS
  - EVALUATION METRICS

▼

ANALYZE EVALUATION RESULTS

- COMPUTE MEASURES OF RISK AND RANGE OF VARIANCE
- CONSTRUCT RISK PROBABILITY DISTRIBUTION FUNCTIONS BASED UPON MEASURES OF RISK AND HISTORICAL RELIABILITY MAINTENANCE CURVE SHAPES
- COMPUTE SUPPORT USER LEVEL OF RISK (HI, MED, LO) AND RISK DRIVERS
- PERFORM TRADEOFF ANALYSIS USING MEASURES OF RISK, RISK DRIVERS, AND HISTORICAL SUPPORT DATA TO DETERMINE POSSIBILITIES FOR REDUCTION OF SS RISK AND CONSEQUENCES OF RESIDUAL RISK
- DETERMINE EVALUATION RELIABILITY

▼

REPORT RESULTS OF EVALUATION

- OVERALL SS RISK HIERARCHY (TO APPROPRIATE REPORT LEVEL)
- HIGHLIGHT SS RISK DRIVERS
- INDICATE ALTERNATIVES TO REDUCE SS RISK
- PRESENT CONSEQUENCES OF ASSUMING SS RISK

Figure 6-1. Integration of RAMSS and the Software Supportability Evaluation Process

c. Conducting the evaluation may occur over a short or long period of time depending upon the level of evaluation being conducted. All members of the evaluation team (test planners, test managers, evaluators, analysts) should be cognizant of the evaluation process and calibration requirements for the evaluation. It is this calibration which reduces the direct misunderstanding of what is to be evaluated, reduces the subjectiveness of the evaluation questions and responses, and improves the evaluation accuracy and reliability.

d. The current evaluation hierarchy is illustrated in figure 6-2. Most of the application of a RAMSS will be during the analysis of evaluation results. First, the evaluation metrics must be converted to risk measures. The conversion can occur at each level in the evaluation hierarchy and represents the relative risk contribution of each component. This process is illustrated in figure 6-3.

e. Since each evaluation question response (as the average of all evaluator responses) has a variance, there is an associated variance in the risk. This variance determines a confidence range about the evaluated software supportability risk.

f. The baseline probability density function derived from actual maintenance data (and perhaps some heuristics) is used to provide insight into how the evaluated risk might be distributed. This provides a perspective on the magnitude of the consequence of the computed risk.

g. From the evaluated measures of risk and the empirical risk probability density functions, it is possible to perform simple tradeoff studies and sensitivity analysis. An extended example in section 6.4 illustrates this analysis. The possible tradeoffs to reduce risk by improving software supportability or modifying the baseline against which risk is determined are easy to explain and ideal for inclusion in reports to decision makers.

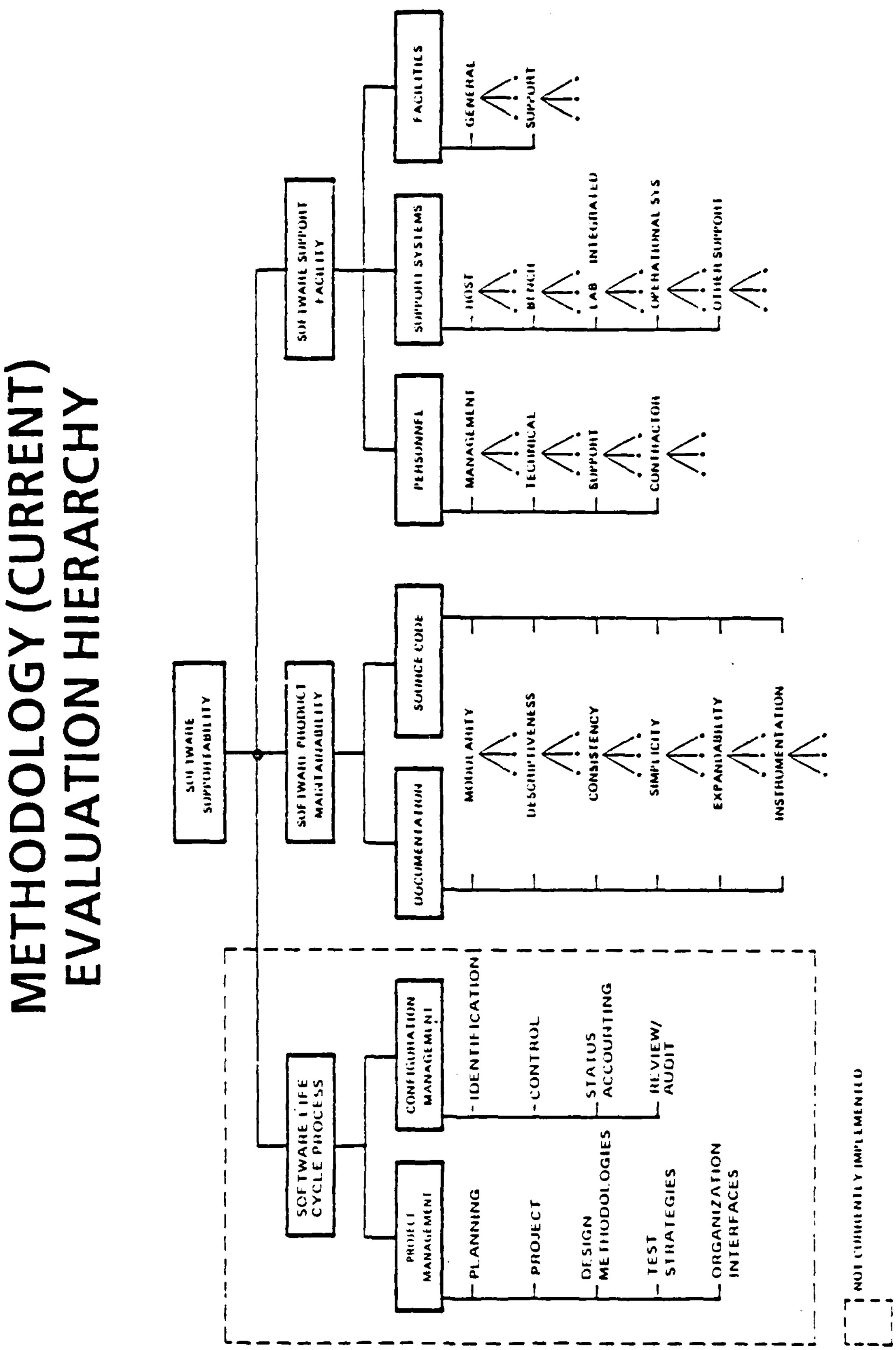


Figure 6-2. Elements of Software Supportability Evaluation

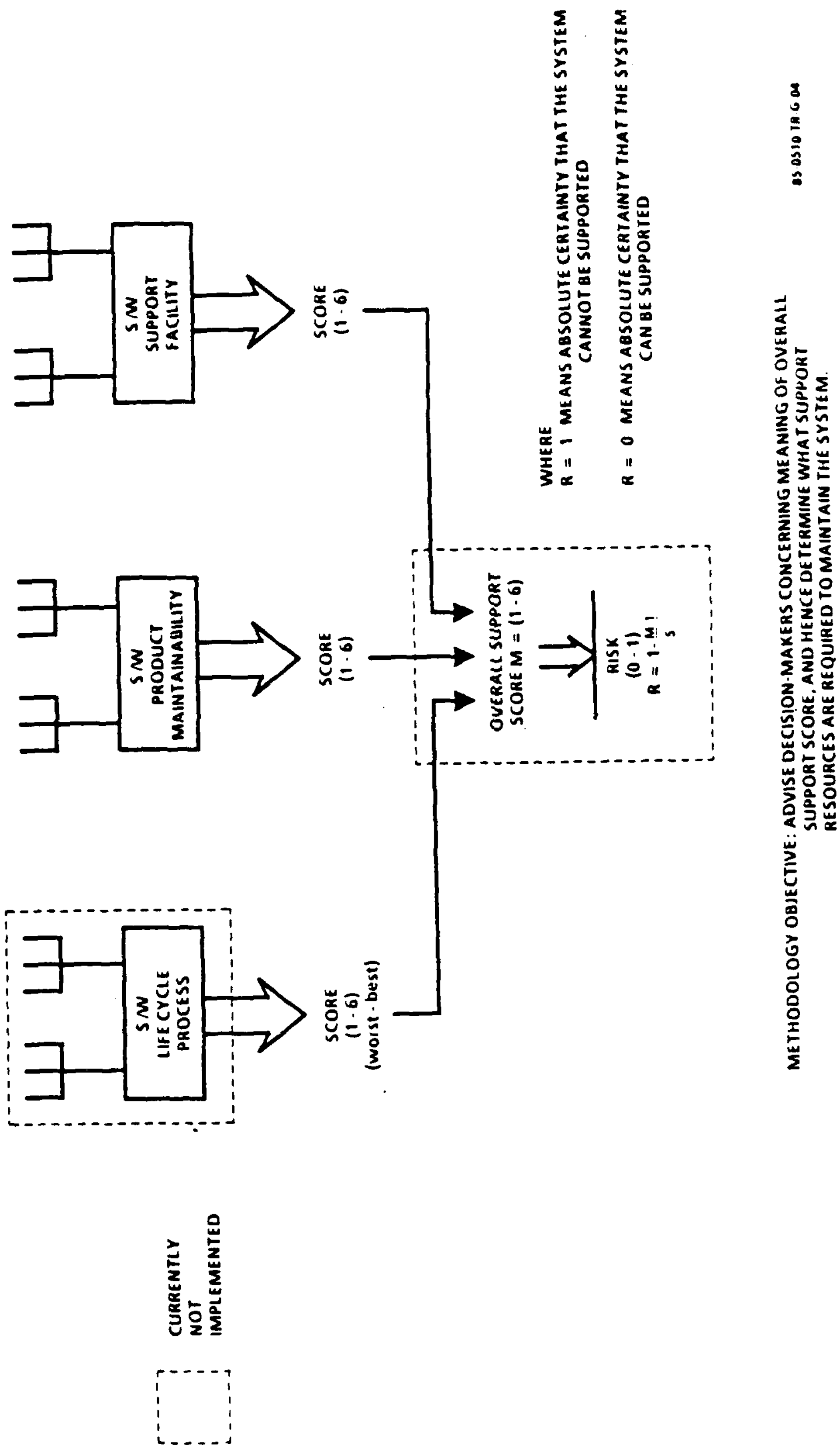


Figure 6-3. Conversion of Software Supportability Metric to Risk

6.4 AN EXTENDED EXAMPLE OF THE METHODOLOGY APPLICATION.

This section contains a hypothetical example of applying the RAMSS framework to an application. The historical profiles used are representative of the data collected, but are not the actual profiles.

6.4.1 Terminology and Foundation.

a. Risk is the potential for realization of unwanted, negative consequences of an event (reference 8.10). Risk assessment focuses upon a means to present that "potential", primarily as a probability. Determining the probability across possible negative consequences of an event, and across applicable events, results in a family of probability density functions. The focus of risk assessment methodologies is upon the derivation of a baseline probability density function representative of the general risk function. Then, risk is defined when a measured or predicted outcome value is compared to the baseline density function. That is, risk is defined by those outcomes (and their probabilities of occurrence) which are negative consequences with respect to the baseline. The consequence of the risk depends upon the impact of the negative events from which the risk is determined.

b. Software supportability is a measure of the adequacy of personnel, resources, and procedures to facilitate the support activities of modifying and installing software, establishing an operational software baseline, and meeting user requirements. Negative outcomes are the result of inadequacy in personnel, resources or procedures to accomplish the above three support activities in an acceptable manner. "Acceptable" is defined relative to the risk

agent's acceptance utility and the baseline probability density function of expected maintenance activity. Thus, a required maintenance action is not necessarily negative. Too many required maintenance actions or the inability to complete a required maintenance action within a specified period of time may be negative depending upon the accepted baseline.

6.4.2 <u>Historical Maintenance Profiles: Example</u>. Suppose the historical maintenance profiles for all systems and for all EW systems are as shown in figure 6-4. In this case, 300 block releases of which 50 are for EW systems have been analyzed. The available person months per change is distributed across the releases as shown in the figure. Because the distributions represent a frequency count they are also probability density functions. The risk to be estimated, computed, reduced, and so forth will be based on the simplistic idea that the more person-months per change allocated to accomplish a block release, the less risk is involved in completing the block release with available resources (personnel, systems, etc.). If more person-months per change is required than allocated by the user/support agreement, then there is unacceptable risk.

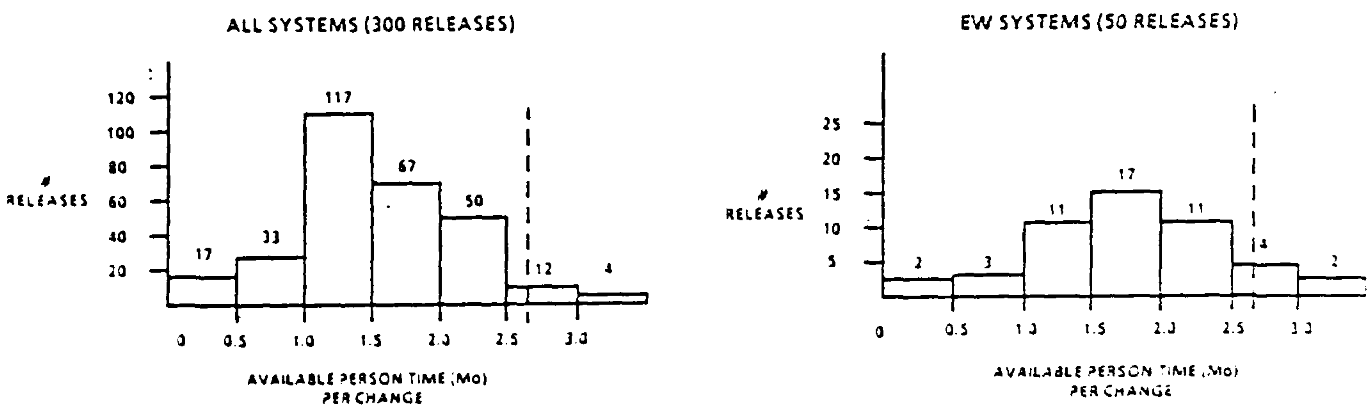


Figure 6-4. Historical Maintenance Profiles: Example

6.4.3 Baseline Agreement: Example. In the process of developing a new EW software system, the user (HQ TAC) and the supporter (Warner Robins ALC) need to arrive at an agreement as to the expected support requirements for the new system. These requirements and the plan developed to satisfy those requirements are specified in the Computer Resources Integrated Support Plan (CRISP) and the Operational/Support Configuration Management Plan (O/SCMP). DT&E and OT&E organizations develop specific test strategies as part of a Test and Evaluation Master Plan (TEMP) and other organization-specific documents. A part of the support requirements should be based upon a user/supporter agreement on the baseline software support profile. For this example, a simplified agreement is presented in figure 6-5.

6.4.4 Baseline Support Profile Risk Computation: Example. The user/supporter agreement of figure 6-5 allows the following computation of expected available person-months per change (see section 4.5.1.3 for more discussion of this computation). The computed value of 2.67 is then plotted on figure 6-4 (as a vertical dotted line). The estimated risk is simply the area under the curve of figure 6-4 to the right of the vertical dotted line. The corresponding risk value for all systems and for EW systems only is shown in figure 6-6. This estimated risk represents the acceptable risk to the user and supporter (since the baseline support profile and support concept from which the risk is derived are acceptable) to accomplish the indicated block release with the specified profile of change requests. The computation of the risk as the "integration" over the risk probability density function is illustrated in figure 6-7.

6.4.5 Evaluating the Software Supportability Risk: Example.

a. The evaluation of software supportability factors (as illustrated in figures 6-2 and 6-3 in section 6.3) is the next step in the RAMSS process. Parts of this evaluation can be conducted throughout the software system acquisition life cycle as is appropriate. The focus of this example is the AFOTEC OT&E evaluation at or near the

- **SYSTEM PROFILE**

SYSTEM: F-16
SWSYSTEM: ALQ-999
SWTYPE: EW
SUPPORTER: WR-ALC
USER: TAC

- **SUPPORT CONCEPT**

RELEASE SCHEDULE: 12 MONTH BLOCK RELEASE WITH 4 MONTH OVERLAP IN RELEASES
SUPPORT STAFF: 5 PERSONS, 80% DEDICATED
SUPPORT FACILITY: "STANDARD" EWAISF

- **BASELINE SUPPORT PROFILE**

BLOCK	TOTAL # CHANGES	TYPE (C, H, V)	COMPLEXITY (H, M, L)	PRIORITY (E,U,N)
1	15	(10, 5, 0)	(2, 4, 9)	(0, 0, 15)
2	20	(8, 12, 0)	(2, 3, 15)	(0, 0, 20)
3	10	(5, 5, 0)	(3, 2, 5)	(0, 0, 10)
4	25	(10, 15, 0)	(1, 6, 18)	(0, 0, 25
5	15	(8, 7, 0)	(2, 5, 8)	(0, 0, 15)

Figure 6-5.. User/Supporter Baseline Support Profile Agreement: Example

BLOCK	AGREEMENT AVAILABLE PERSON TIME PER CHANGE = MONTHS * # PERSONS * %DED. * OVERLAP FACTOR/# CHG'S	RISK ALL	RISK EW
1	= (12 * 5 * .80 * .83) / 15 = 2.67	.04	.10
2	= (12 * 5 * .80 * .67)/20 = 1.61	.39	.61
3	= (12 * 5 * .80 * .67)/10 = 3.22	.03	.06
4	= (12 * 5 * .80 * .67)/25 = 1.29	.61	.77
5	= (12 * 5 * .80 * .67)/15 = 2.14	.17	.28

Figure 6-6. Baseline Support Profile Risk Computation Example (1)

RISK COMPUTATION

$$RISK_1 = \sum_{EAPPC_1}^{\infty} P(\chi_i)\Delta\chi_i$$

EAPPC$_1$ - ESTIMATED AVAILABLE PERSON TIME PER CHANGE FOR BLOCK RELEASE 1

P(x) - HISTORICAL DISCRETE PROBABILITY DIST. FUNCTION

$\boxed{RISK_1 = 14/300 = .04}$	$\boxed{RISK_1 = 5/50 = 0.10}$
$RISK_2 = 0.39$	$RISK_2 = 0.61$
$RISK_3 = 0.03$	$RISK_3 = 0.06$
$RISK_4 = 0.61$	$RISK_4 = 0.77$
$RISK_5 = 0.17$	$RISK_5 = 0.28$

Figure 6-7. Baseline Support Profile Risk Computation Example (2)

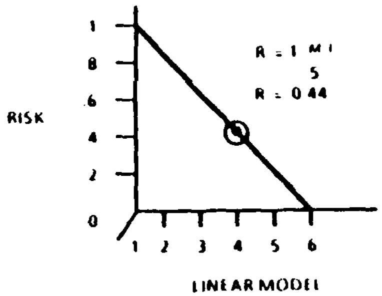
end of the software system full scale development phase prior to initial operational capability.

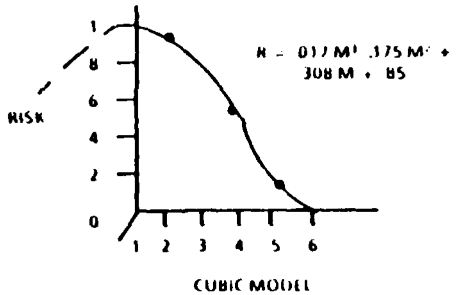
b. The results of the hypothetical evaluation are presented in figure 6-8. The supportability metric conversion to risk and some potential drivers of supportability risk are also shown in figure 6-8. The evaluation is relative to the block release 1. Note the hypothesized non-linear model of the supportability metric to risk conversion. The actual conversion equation is probably shaped more like a hysteresis curve with a very moderate slope at the end points and a very rapid slope between 3.0 and 5.0. A cubic equation

SUPPORTABILITY METRICS (VS BLOCK 1)

<table>
<tr><td>PL</td><td>PR</td><td>OM</td><td>TS</td><td>OI</td><td>ID</td><td>CO</td><td>SA</td><td>RA</td><td>MO</td><td>DS</td><td>CO</td><td>SI</td><td>EX</td><td>IN</td><td>MO</td><td>DS</td><td>CO</td><td>SI</td><td>EX</td><td>IN</td><td>MG</td><td>TE</td><td>SU</td><td>CO</td><td>HO</td><td>BE</td><td>LA</td><td>OP</td><td>OT</td><td>GE</td><td>SU</td></tr>
<tr><td>52</td><td>51</td><td>56</td><td>48</td><td>41</td><td>42</td><td>41</td><td>18</td><td>35</td><td>41</td><td>19</td><td>19</td><td>15</td><td>14</td><td>16</td><td>41</td><td>21</td><td>15</td><td>15</td><td>11</td><td>27</td><td>41</td><td>14</td><td>15</td><td>42</td><td>47</td><td>15</td><td>29</td><td>31</td><td>38</td><td>14</td><td>46</td></tr>
<tr><td colspan="5">PROJECT MANAGEMENT
50</td><td colspan="4">CONFIGURATION MANAGEMENT
34</td><td colspan="6">DOCUMENTATION
34</td><td colspan="6">SOURCE CODE
32</td><td colspan="4">PERSONNEL
38</td><td colspan="5">SUPPORT SYSTEMS
36</td><td colspan="2">FAC
40</td></tr>
<tr><td colspan="9">SOFTWARE LIFE CYCLE PROCESS
42</td><td colspan="12">SOFTWARE PRODUCT
33</td><td colspan="11">SOFTWARE SUPPORT FACILITY
38</td></tr>
<tr><td colspan="32">SOFTWARE SUPPORTABILITY
38</td></tr>
</table>

SUPPORTABILITY RISK COMPUTATION





SUPPORTABILITY RISK DRIVERS

SW LIFE CYCLE PROCESS
SA Status Accounting Procedures and Tools = 18

SW PRODUCT
DOC DS Documentation Descriptiveness = 19
SRC DS Source Code Descriptiveness = 21
SRC IN Source Code Instrumentation = 27
SW SUPPORT FACILITY
LA Laboratory Integrated Test Capability = 29
OP Operational Test Capability = 31

Figure 6-8. Evaluated Suportability Risk: Example

was used for this example, but section IV describes better statistical regression derived alternatives.

c. Henceforth in this discussion, the risk computed as a result of this evaluation will be called the "measured" risk.

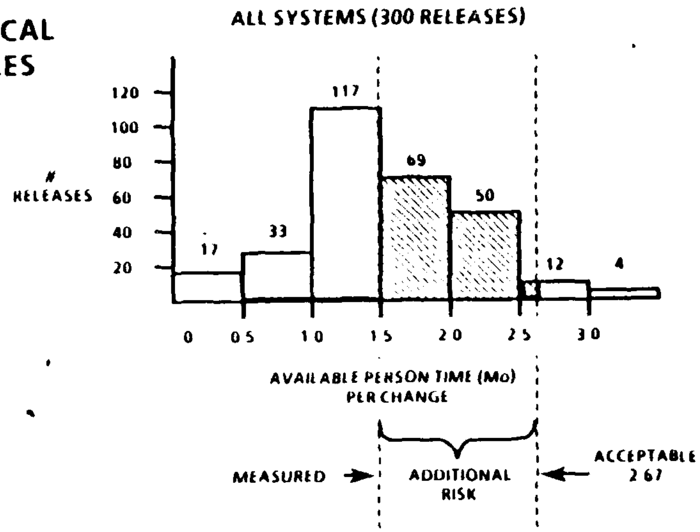
6.4.6 Integration of Acceptable and Measured Risk: Example. Using the acceptable risk and the historical maintenance profiles, the next step is to determine what the required productivity (available person months per change) would be on the basis of the measured risk. This is done by a "reverse integration" technique (simple for this example). The computed risk of 0.44 is the area under the historical profile curve from the required productivity point over all intervals to the right of that point. For the current example, the results of this process are illustrated in figure 6-9. A comparison of the acceptable and measured risk is also shown in figure 6-9.

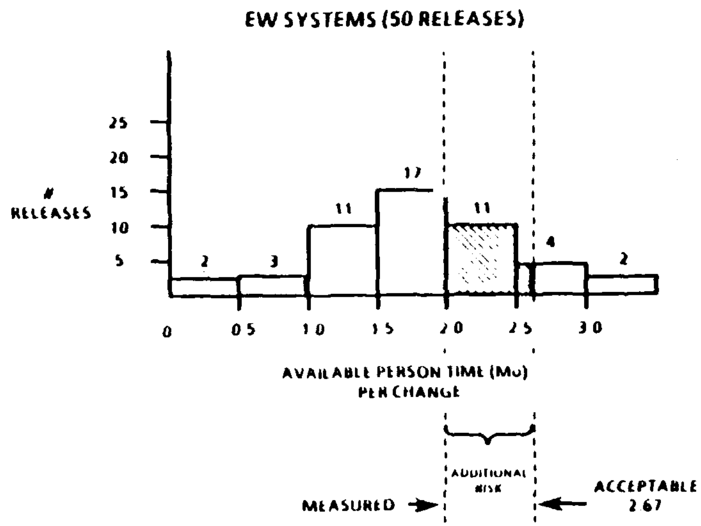
6.4.7 Tradeoff Analysis and Reporting Results: Example.

a. The final step in the RAMSS process is to look for possible consequences of the acceptable and measured risks. If the consequences are not acceptable, then alternatives to reduce either or both risk values are analyzed for cost, schedule, operational, and support impact. Combinations of alternatives (e.g., reducing baseline support profile requirements and improving the software support factors) is a likely approach.

b. Consequences of the acceptable and measured risk for the example are very difficult to assess without more details concerning the particular decision maker focus and the software system's operational use. For our purposes it will be assumed that the consequences of this risk were severe enough to warrant a tradeoff analysis for possible ways to reduce the risk. Some of the alternatives which could be considered for the example are illustrated in figure 6-10. Part

- **HISTORICAL PROFILES**





- **RISK COMPARISON**

	ALL SYSTEMS	EW SYSTEMS	PRODUCTIVITY
ACCEPTABLE RISK	.04	.10	2.67
MEASURED RISK	.44	.44	1.51, 2.0
ADDITIONAL RISK	.40	.34	NA

ADDITIONAL RISK IS THE BASIS FOR TRADEOFF ANALYSIS AND RISK REDUCTION

Figure 6-9. Acceptable and Measured Risk Integration: Example

TRADEOFF CATEGORY	EXAMPLE TRADEOFF	RISK IMPACT (EW ONLY)	EFFECTIVE?
BASELINE AGREEMENT AVAILABLE PERSONS	5 PERSONS → 6 PERSONS	ACCEPTABLE RISK: .1 → .02 MEASURED RISK: .44 → .43	NO
BLOCK RELEASE SCHEDULE	12 MO / 4 MO OVERLAP → 15MO /NO OVERLAP	ACCEPTABLE RISK: .1 → .01 MEASURED RISK: .44 → .38	MAYBE
CHANGE REQUEST PROFILE (BLOCK 1)	15: (10, 5, 0); (2,4,9); (0, 0, 15) 10: (8, 2, 0); (1, 2, 7); (0, 0, 10) ←	ACCEPTABLE RISK: .1 → .01 REGRESSION PERSON TIME: 2.46 → 1.51 MEASURED RISK: .44 → .35	MAYBE
ACCEPTABLE SUPPORTABILITY RISK HISTORICAL SUPPORT PROFILES	VARIANCE OF ± 20% IN PROFILE AVAILABLE PERSON TIME	ACCEPTABLE RISK: .1 → (.01, .30) MEASURED RISK: .44 → .44	MAYBE
BASELINE RISK ESTIMATION	VARIANCE OF FACTORS INCLUDED IN RISK ESTIMATION (E.G. % DEDICATED, RELEASE OVERLAP) ± 20%	ACCEPTABLE RISK: .1 → (.01, .30) MEASURED RISK: .44 → (.38, .50)	MAYBE
PERSONNEL NUMBER & SKILL	SIMILAR TO BASELINE RISK ESTIMATION FOR OTHER FACTORS	ACCEPTABLE RISK: (AS ABOVE) MEASURED RISK:	MAYBE
MEASURED SUPPORTABILITY RISK SUPPORTABILITY METRIC ACCURACY	VARIANCE OF ± 20% IN ACCURACY	MEASURED RISK: .44 RISK RANGE BOUNDS (.28, .59)	YES
SUPPORTABILITY RISK ALGORITHM	$R = 1 - \frac{M-1}{5}$ (linear) → $R = aM^3 + bM^2 + cM + d$ (cubic)	MEASURED RISK: R (linear) = .44 R (cubic) = .43	NO (MAYBE)
SUPPORTABILITY RISK DRIVERS	STATUS ACCOUNTING 1.8 → 4.1 DOCUMENTATION DESCRIPTIVENESS 1.9 → 4.3 SOURCE CODE DESCRIPTIVENESS 2.1 → 5.0 LAB-INTEGRATED TEST CAPABILITY 2.9 → 5.0	MEASURED RISK: M: 3.8 → 3.86 R: .44 → .43 M: 3.8 → 3.83 R: .44 → .43 M: 3.8 → 3.85 R: .44 → .43 M: 3.8 → 3.81 R: .44 → .44 ALL METRICS M: 3.8 → 4.06 R: .44 → .39	NO NO NO NO MAYBE

85 0510 TR G 02

Figure 6-10. Tradeoff Analysis: Example

of the reluctance to consider a particular alternative as being effective is the lack of specific detailed information. Tradeoff analysis is not a cookbook process. The preliminary nature of the RAMSS and the use of hypothetical data also limits confidence in the effectiveness of alternatives. The importance of the example is to illustrate that logical tradeoffs can be considered, and the impact upon the acceptable and measured risk can be graphically illustrated in a reasonably simple way. This is a major consideration for adequate presentation of results to the various levels of decision makers.

6.5 PROBLEMS AND OBSERVATIONS.

The framework for a RAMSS as it has evolved during this study and as it is reviewed in this chapter has good potential for practical application. Some problems and observations are listed below:

(1) A central, valid historical maintenance profile data base needs to be developed. This data collection effort supports the capability for such a data base to be developed and maintained over time.

(2) The RAMSS supportability evaluation upgrade is necessary. The product evaluation would be least affected. The life cycle software support management evaluation was considered to be important by personnel surveyed.

(3) The supportability evaluation metric to risk conversion and relationship to the historical baseline maintenance profiles needs to be further clarified.

(4) A pilot study applying the RAMSS framework is recommended.

VII. Conclusions/Recommendations

SECTION VII

CONCLUSIONS/RECOMMENDATIONS

7.1 INTRODUCTION.

a. In addition to some general conclusions and recommendations from this study, this section of the report presents some important problems which were observed during the process of collecting software support activity data during the facility visits.

b. All of these problems are "negative," in the sense that their causes interfere with or detract from the capabilities of the various support facilities to perform their missions. This in no way implies that the support facilities are not performing effectively. But they could perform more effectively. We found the support facilities staffed by qualified, motivated people who were extremely cooperative in support of this study. The observations and problems noted below do not have simple solutions, but because they were common to almost all facilities and systems examined, it seemed appropriate that they be documented. An improvement in some of these areas could provide significant enhanced capability for software support at some facilities. Improvements in other areas would make the data collection for future studies like this one much easier.

c. General conclusions and recommendations will be discussed concerning the data collection process, the software supportability risk computation, historical maintenance profiles, and the supportability problems observed during the site visits. Finally, a list of conclusions and recommendations from this study will be discussed.

7.2 DATA COLLECTION PROCESS.

The data collected during this study effort provided valuable insight into the software support process at various sites. There are many other sites which were not visited, and a large number of software systems for which data were not collected. In order for the survey data to remain current and improve in quality, it is necessary to adapt some method for obtaining new data and updating the current historical maintenance profiles and the associated analysis results. This section briefly describes the conclusions and recommendations concerning the data collection process.

7.2.1 Study Effort Data Collection. The data collected during the study effort included background, evaluation, and software release data from each software system as well as observation and interview data from the site visits. The conclusions concerning the data collection process are summarized below.

(1) The site visit was essential in order to obtain the data.

(2) The AFOTEC preparation prior to the site visit was very valuable and was probably the main reason the site personnel were so cooperative during the site visit.

(3) Having a site survey form was essential in order to quickly focus site personnel upon the purpose of the survey.

(4) The background and evaluation data on the site survey form were relatively easy to collect, with the exception of an estimate of supportability risk; the problem in this case was lack of a clear definition of what was being assessed for risk. As the site visits progressed, the definition of this risk was clarified and the data became more consistent and accurate.

(5) The software release data was difficult to obtain. This difficulty was primarily due to the necessity to reconstruct prior release data rather than the inability to record such data. It was determined that the release data requested could be easily recorded during the release effort.

(6) In general, the data obtained are probably of somewhat low validity. That is, the consistency of the data is weak and the accuracy of the data is low. Variance within the data is too high for statistically strong significant results. However, it appeared that most of the more important data could be improved a great amount through a more regular data collection effort (during the release effort).

(7) Storage of the collected data in a dBASE III data base was very valuable and allowed easy generation of reports for analysis review.

7.2.2 Recommended Future Data Collection Procedure. It is necessary to continue to collect data similar to the site survey data. It is also necessary to make the data collection process efficient for site personnel and somewhat related to activity already being accomplished. A recommended data collection form and procedure is discussed in section III. The essential elements of the form and procedure are:

(1) The form and procedure are temporary until a more permanent arrangement can be integrated into the Air Force software support concept.

(2) All cognizant software support sites and major (critical) software systems currently being supported should be required to participate in the data collection effort.

(3) It is estimated that completion of the data collection form (and altering current practices so the data are readily available) would take very little additional personnel time. The range might be from one person day to one person week per release.

(4) The data collection form data elements required for each release include: site, system, software system, software system type, size in thousands of source lines, source languages, personnel counts and skill levels, release identifications, release start dates, engineering completion dates, field release dates, and baseline software support profile data on each change request in the release.

(5) The data collection procedure would involve each support site completing a data collection form for each software system release. The form would be sent to a data repository site (AFOTEC, at this time) for integration into the current data base, update of the historical maintenance profiles, and further statistical analysis.

(6) It is recommended that such a data collection form be adapted and that AFOTEC develop the necessary data base and analysis environment to support regular revisions to the historical maintenance profiles.

7.3 SOFTWARE SUPPORTABILITY RISK COMPUTATION.

a. The initial approach of the RAMSS to software supportability risk computation is reported in reference 8.3. This approach used a simple linear conversion of the software supportability evaluation metrics. Analysis was conducted to determine the validity of this approach, and perhaps derive alternative approaches. Details of this

analysis are presented in section IV. Essential conclusions and recommendations from this analysis are discussed below.

(1) The analysis indicated very little support for using a linear conversion of the software supportability metrics. The boundary cases were supported, but the data were better fit by a curved line than a straight one. Details of this analysis are presented in section 4.4.1.

(2) A linear regression model was derived which more accurately described the relationship between the software supportability metric (overall general score) and software supportability risk. The regression equation is described in section 4.4.1.2 and can be reasonably easily used for computation of risk with a hand calculator.

(3) A factor regression model was derived which even more accurately described the relationship between the software supportability metrics and software supportability risk. The factor regression model was based on six derived factors, and four factors (support management, product, personnel, and software support systems) of the six were significant drivers of software support risk. The factor regression model and equation are described in sections 4.4.2 and 4.4.3. The computation of software supportability risk is relatively involved, but is easily accomplished using a computer.

b. A comparison of the three models for computing software supportability risk is presented in section 4.4.4. The recommended model is the factor analysis regression model. This model has the highest R^2 value which accounts for the variation of the transformed risk values about their mean. It should be cautioned that the R^2 is not very "strong" for any of the models and care should be taken in using them.

c. The linear regression model and the simple linear model can be used as a check against the factor regression model as future data are collected and the analysis results updated. Because of the comparatively low confidence in the data itself, the updated analysis may show more complete and surely more valid results.

7.4 MAINTENANCE PROFILES AND RELEASE DATA.

a. The historical maintenance profiles are derived from the software system release data. These profiles are a histogram with an X-axis representing discrete ranges of person-months per change and the Y-axis representing a count of the number of software system releases in each of the discrete X-axis ranges. The historical maintenance profiles are presented in section V and the analysis results of the software release data are presented in section 4.5. Essential conclusions and recommendations from this analysis are discussed below.

b. The historical maintenance profiles were constructed for all software system releases, and also for stratified subsets by site and by software system type. Regression analysis was then performed using person-months per change as the dependent variable and various independent variables. The analysis attempted to determine if a linear regression model existed for predicting person-months per change from the independent variables rather than computing the value as a ratio (whose terms exist only after the release is done, not prior to the release). Independent variables included number of source lines in thousands, proportion of correction change requests, proportion of changes of low complexity, proportion of changes of normal priority, percentage of high-level language source code average skill level of personnel, and indicator variables for software types.

c. Results from the regression analysis showed no clear, consistent relationship between available person-months per change and the independent variables, save for those indicating the several software types. Because software type was shown to be a significant factor with respect to available person-months per change, separate profiles should be used for the various software types in assessing risk. Although none of the other independent variables were shown to relate to available person-months per change, the possibility still exists that given better data, significant relationships might be found. Thus it is recommended that these analysis techniques be used during the future update of the data on software releases to confirm or negate the hypotheses which are briefly outlined below. Use of <u>actual</u> person months per change (as specified in the recommended data collection form) as opposed to <u>available</u> person-months per change may also affect the analysis results.

(1) <u>Hypothesis 1</u>. The percentage of low complexity change requests in a software release is negatively correlated with the person-months per change. That is the higher percentage of low complexity change requests, the lower the person-months per change.

(2) <u>Hypothesis 2</u>. The percentage of high-level language source lines in a software release is [weakly] negatively correlated with the person-months per change request.

(3) <u>Hypothesis 3</u>. The average skill level of personnel, proportion of correction change requests, and proportion of normal priority change requests are not correlated with person-months per change.

d. The first two hypotheses can be explained in a rather straightforward manner since complexity is directly tied to effort level and it is generally accepted that it is easier to maintain software written in a high order language.

e. The third hypothesis is not as easily explained, but a specific understanding of the dependent variables helps build a logical rationale. There is no doubt that normal priority changes received lower priority, but there was definitely no trend that indicated normal priority requests were any more or less difficult to accomplish than non-normal (urgent and emergency) change requests. A similar statement holds for correction change requests. However, it would appear that the greater the average skill level, the more quickly change requests could be completed. In a more pure environment that may be true, but it is a rare environment in which personnel skills do not range over the full scale of 1 (lowest) to 5 (highest). Furthermore, the more highly skilled personnel are given the more difficult changes, which tends to result in similar person-months per change values. Finally, most changes in a release are of low complexity and many times it takes more highly skilled personnel about the same amount of time to complete such changes as it does the average personnel.

f. In argument against the average skill level of personnel hypothesis, it is strongly suspected that the average skill level and percentage of low complexity change requests may in combination relate to person-months per change. This is one reason it is recommended that skill level of personnel be collected during future data collection efforts.

g. It is recommended that the historical maintenance profiles be continually updated with data derived from the recommended future data collection procedure and associated form. All support sites and major software systems should be represented in future historical maintenance profiles.

7.5 GENERAL PROBLEMS OBSERVED DURING SITE VISITS.

a. The problems discussed below were noted at most facilities, and hence have general application. When possible, specific recommendations for improvement are noted.

b. The problems discussed in this section are summarized below:

Table 7-1.

Summary of Problems

	Problem	Solution
1.	High personnel attrition rate	Requires further study
2.	Inconsistent application of software configuration management system (CMS)	Set and enforce standard CMS procedure
3.	Lack of agreement on definition of terms	Terms defined as part of standard CMS
4.	Modification to software takes too long to reach the field	Study modification and testing process to streamline
5.	Systems support dedicated to multiple ALCs	Requires concept change for ALC operation
6.	Contractors not transferring responsibility for software support	Need more information
7.	Constraints on OFP software development	None. Problem recognition required

7.5.1 Personnel Attrition Rate.

Problem

a. One of the most common problems noted was the high attrition rate of personnel assigned to software support. The biggest contri-

butor to this problem appeared to be the higher salaries and career opportunities available from government contractor organizations. Some support organizations were severely affected by this problem. Turnover was reported as being between 20 percent and 40 percent per year in some instances. To a lesser degree, the duty rotation of military personnel also had significant impact. Due to the highly technical, complex nature of emerging weapons systems, the training required to bring new personnel to an effective level of job performance is very time consuming. When it takes 18 months to train a new employee and he or she leaves after 3 years, only to be replaced by a new employee who needs training, the overhead is high. Many young military personnel, if they are not lost due to transfer, are lost by obtaining higher paying jobs with government contractors at the completion of their military obligation.

Solution

b. There is no simple solution to this problem. It would seem that salaries and career opportunities for government employees are not as great as for civilian contractors, therefore improvement in pay and benefits are significant issues. On the other hand, one could argue that civilian contractors are overpaid, and that action should be taken to remedy this situation. It is not in the scope of this study to address this problem, except to mention that the problem exists, and that it is serious. Some relief for military personnel might be to lengthen the active duty tour at software support facilities. However this solution has potential negative effects on military careers. An independent study should be made concerning the attrition issue, and specific recommendations made for its resolution.

7.5.2 Inconsistent Application of Software Configuration Management.

Problem

a. There are really two problems here. The first problem is that no software support facility that was visited was tracking or recording software maintenance data in a manner consistent with that of any other facility. Each software system was using its own method for performing software configuration management. One bright spot in the study was that at least everyone seemed to be using some form of software configuration management. However, it was expected that at least the configuration management systems used on different software systems located at the same facility in the same building managed by the same organization would have high degrees of similarity. This was simply not true. There appears to be a great amount of disagreement surrounding what items should be monitored and what information should be tracked by a configuration management system.

b. The second problem with the maintenance data was caused by the first. It was extremely difficult to collect the data needed for this study, because such data was very rarely maintained in a form that was readily accessible. The desired information was usually present, but the inconsistency in storage methods necessitated extra time to extract it. Some configuration methods were mostly automated, some partially automated, and some almost totally manual. The automated methods, when done properly, were the easiest and quickest methods for obtaining desired information. Had there been at least a consistent configuration management system, the data would have been easier to extract. This condition, unless rectified, will continue to be a problem for efforts by AFOTEC to establish new historical profiles in future years.

Solution

c. These problems are workable. It is not expected that each software configuration management system (CMS) collect, store, and retrieve the same information using the identical methodology. What is reasonable, however, is that each CMS maintain some finite set of information consistently and accurately across all software systems. There is a lot of literature currently available about CMS. What is lacking is a standard set of procedures to be used and data items to be collected. If this standard were set and enforced for all government software support facilities, then future studies such as this one would be much easier. However, the reason for setting a standard should not be to accommodate studies. The reason should be that a good CMS means software maintenance is under control and is being properly performed. A good CMS provides (among other things) the maintenance effort with a management tool that increases the ability to properly allocate limited resources while decreasing the probability that errors are introduced during the maintenance process. A separate study should be performed which recommends a standard set of CMS procedures and data items for DoD software support facilities, with the data desired by this study as a preferable start point. Given a standard CMS, AFOTEC could collect the information to update future baselines without having to make costly facility visits. An initial approach to solving this problem is discussed in section 3.6 of this report.

7.5.3 Lack of Definition Agreement.

Problem

a. This problem may be a contributory factor to the problems discussed in section 7.5.2, in the sense that there has been disagreement in the software community about what activities should be tracked or called software maintenance. This study recommends

that the categories of maintenance requests be priority type, maintenance type, and complexity level. This study also recommends that the software maintenance types be called corrections, enhancements, or conversions. Some authorities in the software community do not consider enhancements to be software maintenance activities at all. In addition, this study showed that many of the software support maintenance activities which should be categorized as conversions were in fact called corrections or enhancements by the support facilities. In the same manner, the categorization of priority into emergency, urgent, or normal, and that of complexity level into high, medium, or low, are not clearly understood. Hence, the lack of a standardized set of definitions is inhibiting the collection of common data across maintenance systems.

Solution

b. This study proposes definitions for the above categories of software maintenance activities. The glossary (appendix B) contains definitions of the controversial terms. These definitions are summarized in table 7-2. While these definitions may be argued, they have at least been applied consistently in this study and are recommended for adoption.

7.5.4 Software Release Process Takes Too Long.

Problem

a. There were several instances during this study when mention was made of the unreasonably long time that is required for a software modification to be completed and put into the field. This time is measured from the date the software support facilities actually begin work on the modification to the time it is operationally available. Current figures indicate that 18 months is about the average time for this to occur, of which about 11 months is software

Table 7-2.

Definition of Maintenance Activity Terms

Maintenance Request Category -- the identification of a maintenance request by specification of the priority type, maintenance type, and complexity level.

Maintenance Type -- the type of maintenance actions required to complete a maintenance request: enhancement, conversion, correction.

Corrective Maintenance Action (MA) -- any change which is necessitated by actual faults (induced or residual) in a software system.

Enhancement (perfective) MA -- any change, insertion, deletion, modification, extension, and enhancement made to a software system to meet the evolving needs of the user.

Conversion (Adaptive) MA -- any change/effort to a software system which is initiated as a result of changes in the environment (e.g., hardware, system software) in which the software system must operate.

Priority Type -- the criticality of the maintenance request in order to preserve mission readiness: emergency, urgent, normal.

Emergency MA -- an MA requiring all available personnel's dedicated effort to correct the problem as soon as possible (e.g., 24 hours); MIL-STD-1679 severity code 1 or 2: mission termination or severe degradation

Urgent MA -- an MA requiring next "block release" turnaround; MIL-STD-1679 severity code 3: mission impact

Normal MA -- an MA not in the Emergency or Urgent categories; MIL-STD-1679 severity code 4 or 5: mission inconvenience

High Complexity MA -- an MA where changes are in requirements, design, code, and test; or > 10 percent of CSCI is affected; or several modules are affected by the change (global changes); or the technical nature of the change requires highly specialized personnel skills; or the level of effort by personnel is large

Medium Complexity MA -- an MA where changes are in design, code and test; or between 1 percent and 10 percent of CSCI is affected; or at least two modules are affected by the change (semi-local); or the level of effort by personnel is average.

Low Complexity MA -- an MA where changes are isolated to only one unit (e.g., one module/compilation unit) or code; or no more than 1 percent of CSCI is affected; or the level of effort by personnel is minimal

modification and 7 months is field (operational) testing. Many felt that this period of time could be decreased, with considerable benefits to the weapon system.

Solution

b. This problem has no easy solution. Most personnel interviewed were frustrated by the (to them) unreasonable time to perform operational testing. However, there are undoubtedly many constraints in this area that support facilities are simply not aware of. It is recommended that this problem be given further study.

7.5.5 Multiple ALCs Supporting Same System.

Problem

a. Several instances were reported in which one ALC may be the OPR for a given software system, but another ALC or organization may be doing the support function. At other times, changes to software being supported at one ALC may affect another system, and hence the software support of that system, at another ALC or organization. This situation often creates tremendous coordination and communications problems, further complicating the already difficult job of adequately supporting software changes.

Solution

b. Due to the construct of the ALC system, where weapons systems are spread around to the various ALCs, this problem is unlikely to be reduced unless there is a change in support location philosophy.

7.5.6 Contractor Not Transferring Responsibility for the Software.

Problem

a. In some cases, the support facilities have been staffing and training personnel in anticipation of performing the software support function, only to have the PMRT date slipped for one reason or another. Sometimes the contractor is still performing maintenance under a "guarantee" agreement. For the F-16 WST at Ogden ALC, the software support team has been providing interim releases of software change requests which the contractor cannot get into the baseline releases. Under continually slipping PMRT dates, the government support facilities have found it difficult to establish the baselines for software support required to perform the maintenance function.

Solution

b. Without knowing more about why the systems are not undergoing PMRT, it is difficult to recommend an overall fix for this problem. However the problem was mentioned often enough to warrant recognition.

7.5.7 Constraints on OFP Software Development.

Problem

a. Many times the problem with making software changes to F-4 and F-16 operational systems (as well as other OFP systems) is as dependent upon the memory size available for the systems as upon the availability of the people to do the work. Often, adding enhancements may require the unplanned complete removal of an existing capability just to create the memory space to make the enhancements. This restriction creates unique problems in embedded software.

Solution

b. There is no immediate solution to this problem. As hardware technology improves to allow more memory space for software, some of this problem may be resolved. For the time being all one can do is recognize the problem and make the best of it.

7.5.8 General Observations.

a. The following comments cannot really be categorized as problems, but are instead observations about the apparent characteristics of software support activities.

b. At the beginning of this study, one of the elements of the desired software maintenance activity data to be collected was the actual person-hours per change. After several attempts to collect this data, it became clear that the data was not available. Two basic reasons for this were: 1) There is no good mechanism for recording such information, and 2) when people work on software projects (or almost any project for that matter) it is very difficult to define which time should be counted toward completing the task. It was learned during the facility visits that many activities are being performed by software maintenance personnel which are not directly software maintenance activities. For accountability of time and resources, it was apparent from the maintenance data that actual logged project maintenance time and actual project configuration management time are a small part of the overall support time. Such things as waiting for testing on a simulator, waiting for a simulator to be repaired, lack of work because the facility is staffed but the system has not been released to the government, or training time (new and old personnel), etc., are not directly acountable. Other items which are not logged include review and support of externally requested tests, monitoring contractor development/delivery/support, political strategy meetings, and update of documentation and

facilities. The amount of time spent actually performing software change activity may vary from 30 percent to 90 percent of the time available.

c. Due to the unavailability of person-hours per software change, the unit of measure for productivity became available person-months per block release. Each block release is composed of a group of changes. This measure is computed by knowing how long the block release was worked, and how many personnel were assigned to the task for that length of time. Then the baseline ("cost" in person-months per change as a function of number of block releases with that "cost") includes all of the overhead time mentioned in the previous paragraph. This measure is more reflective of the time that is actually spent in doing the total software support function and, in the final analysis, may be more realistic.

7.6 CONCLUSIONS/RECOMMENDATIONS.

a. It should be clear that the process of providing software support for major weapons systems is a complex and highly labor-intensive task, with a lot of room for improved methods of providing high quality, cost effective systems on a timely basis. This report has discussed some issues which were not directly related to how to perform risk assessment. But, the resolution of these issues would reduce the risk of software supportability should a risk assessment be performed. These issues include high personnel attrition rate, ineffective configuration management systems, inconsistent terminology applications, lengthy time to produce operational changes, multiple ALC support, delay of PMRT, and poor constraints on OFP software development.

b. The most significant conclusion, which supports the primary goal of this report, is that the results of this study indicate that the software support data justify further refinement and

verification of a risk assessment model. Analysis of the data indicates that, by virtue of this study, the methodology has been improved and is now ready for partial application via a pilot study. Full application is not possible because the software life cycle evaluation tool has not been developed, and the other evaluation tools require update to conform to the RAMSS. The following ordered steps are required to provide a RAMSS which fulfills the total objectives:

(1) Adapt the software maintainability tool to measure against the user/supporter baseline.

(2) Adapt the software support facility evaluation tool (ASSET) to measure against the user/supporter baseline agreement.

(3) Complete the top level software life cycle process evaluation metrics for risk assessment (RA).

(4) Apply the software supportability risk assessment methodology to a current program. Evaluate results of the application and complete technology transfer to AFOTEC personnel.

(5) Continue the collection of software system release data.

(6) Develop procedures to update the historical maintenance profiles and analysis results from the newly collected software system release data.

(7) Continue to evolve the software supportability risk computation regression analysis results. Use the factor regression model, the linear regression model, and the simple linear model in that order of preference.

(8) Continue to analyze potential relationships between person-months per change and other system-level variables, such as percentage of low complexity change requests.

VIII. References

SECTION VIII

REFERENCES

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A. Acronyms

APPENDIX A
LIST OF ACRONYMS

ACM	Air Combat Maneuvering
ADPF	Automatic Data Processing Facility
ADTS	Avionic Depot Test Station
AF	Air Force
AFB	Air Force Base
AFOTEC	Air Force Operational Test and Evaluation Center
AGEOP	Aerospace Ground Equipment Operating System
AIS	Avionics Intermediate Shop
AISF	Avionics Integration Support Facility
ALC	Air Logistics Center
ALCM	Air Launched Cruise Missile
AOCP	Airborne Operational Computer Program
APT	Available Person Time
ASIT	Adaptable Surface Interface Terminal
ASSET	AFOTEC Software Support Evaluation Tool
ATC	Air Training Command
ATD	Aircrew Training Device
ATE	Automatic Test Equipment
AWACS	Airborne Warning and Control System
BMDP	BMDP Statistical Software (NOTE: BMDP is a name, not an acronym.)
BNST	Bomb Navigation Station Trainer
BTG	Blue Tape Generator
C-E	Communications-Electronics
C3I	Command/Control/Communications/Intelligence
CADC	Central Air Data Computer
CAFMS	Computer Assisted Force Management System
CC	Central Computer
CDR	Critical Design Review
CI	Configuration Item
CITS	Central Integrated Test System

CM	Configuration Management
CMP	Configuration Management Plan
CMS	Configuration Management System
CPT	Cockpit Procedure Trainer
CRISP	Computer Resources Integrated Support Plan
CSCI	Computer Software Configuration Item
CSS	Communications System Segment
DBR	Engineering Duration of the Block Release (months)
DC/SR	Display Control/Storage Retrieval
DPS	Data Processing System
DT&E	Development Test and Evaluation
DOD	Department of Defense
ECS	Embedded Computer System
EMUX	Electrical Multiplex System
EVS	Electro-Optical Visual System
EW	Electronic Warfare
F/CGMS	Fuel/Center of Gravity Management System
FCC	Fire Control Computer
FCR	Fire Control Radar
FESP	Facility, Equipment, and Software Support Plan
FTSS	Flight Test Simulation System
FTSS	Flight Test Support System
GLCM	Ground Launched Cruise Missile
HQ TAC	Headquarters Tactical Air Command
HUD	Head-Up Display
II	Imagery Interpretation
INS	Inertial Navigation System
IOC	Intial Operational Capability
ISA	Interface Simulator Analyzer
IV&V	Independent Verification and Validation
JTIDS	Joint Tactical Information Distribution System
L/P	Line Printer
L1T	Level 1 Test
LASER	Light Amplication by Stimulated Emission of Radiation

LPT	Loaded Pylon Test
LRU	Line Replaceable Unit
M-DTD	Maintenance-Data Transport Device
MA	Maintenance Action
MARRES	Manual Radar Reconnaissance Exploitation System
MC-1 EXEC	B-52 Block I OFP Exec
MC-2 EXEC	B-52 Block II OFP Exec
MDS	Modular Display Sub-System
MDTS	Mission Data Transfer System
MEBU	Mission Essential Backup
MPT	Missile Procedures Trainer
NCS	NORAD Computer System
NORAD	North American Aerospace Defense Command
NP	Number of Persons Assigned to Software System
OC-ALC	Oklahoma City ALC
OCP	Operational Computer Program
OFP	Operational Flight Program
OFT	Opeational Flightcrew Trainer
OO-ALC	Ogden ALC
OPR	Office of Primary Responsibility
ORS	Offensive Radar System
O/SCMP	Operational/Support Configuration Management Plan
OSTF	Off-Site Test Facility
OT&E	Operational Test and Evaluation
PAVE TACK	Electronic Optical System for Laser Guided Weapons
PDR	Percentage of the Persons Dedicated to the Block Release
PDS	Percentage of the Persons Dedicated to the Software System
PMD	Program Management Directive
PMP	Program Management Plan
PMPC	Person-Months per Change
PMPCHNG	Person-Months per Change
PMRT	Program Management Responsibility Transfer
PO	Program Office
PROM	Programmable Read-Only Memory

QA	Quality Assurance
RA	Risk Assessment
RAMSS	Risk Assessment Methodology for Software Supportability
RF	Radio Frequency
S/W	Software
SIM	Simulation
SM-ALC	Sacramento ALC
SMCP	System Maintenance Computer Program
SMS	Stores Management System
SP/USER	Signal Processor User Simulator
SPACECOM	Space command
SRAM	Short Range Attack Missile
SRCP	Surveillance Radar Computer Program
SRGSCP	Surveillance Radar Ground Support computer Progream
SS	Software Supportability
SS	Software Support
SSC	Space Surveillance Center
SSF	Software Support Facility
STRTS	Simulator Tactical Radar Training System
SUP	Support Utility
SYS	System
TACS	Tactical Air Control System
TC	Time to Complete Maintenance Request
TEMP	Test and Evaluation Master Plan
TEREC	Tactical Electronic Reconnaissance
TIPI	Tactical Information Processing Interpretation
TPOCP	Tran_lator Process Operational Computer Program
UTIL	Utility
UUT	Unit Under Test
WCS	Weapon Control System
WNC	Weapon Navigation Computer
WR-ALC	Warner Robins ALC
WST	Weapon System Trainer

B. Glossary

APPENDIX B

GLOSSARY OF TERMS

B.1 INTRODUCTION.

a. The glossary of terms for the RAMSS has varied as the methodology development has progressed. Refer to BDM/A-84-322-TR (Final) dated September 28, 1984, for a complete glossary of terms relating to risk assessment.

b. Some terms have more than one description; when this is the case, the descriptions either:

(1) Are significantly different between sources (though the effective meaning may be not much different)

(2) Are used differently (different users or technical language)

(3) May be found within the context of a different source

(4) Have real differences in meaning.

Both DoD and non-DoD (e.g., FIPS PUBs, NBS Special Publications) sources are used. The non-DoD sources and terms are not mandated for our use, but are rather included for breadth of understanding, for those relevant terms commonly used with the non-DoD governmental and/or private sectors.

c. The source of each description is indicated by a symbol in parentheses before that source's term description:

$TERM_1$

  $(SYMBOL_{1.1})$

  $Description_{1.1}$...

  $(SYMBOL_{1.2})$

  $Description_{1.2}$...

  .
  .
  .

  $(SYMBOL_{1.n})$

  $Description_{1.n}$...

$TERM_2$

  .
  .
  .

$TERM_N$

The symbols used and corresponding sources are:

(AFOTECP1)	AFOTECP 800-2, Volume I, 10 Nov 82, "Software Test Manager's Guide."
(AFOTECP3)	AFOTECP 800-2, Volume III, 1 Jan 84, "Software Maintainability Evaluator's Guide."
(AFR800-14)	Air Force Regulation 800-14, Volume I, "Management of Computer Resources in Systems," 12 Sep 75.
(AFR300-15)	Air Force Regulation 300-15, "Automated Data System Project Management," Jan 78.
(AFOTECP5)	AFOTEC 80-2, Volume 5, 25 Jul 83, "Software Support Facility Evaluation--User's Guide."
(ROWE)	Rowe, William, An Anatomy of Risk, John Wiley, 1977.
(AFR205X)	Air Force Regulation 205-16, "Automatic Data Processing (ADP) Security Policy, Procedures and Responsibilities," 1 Aug 84.
(CURRENT)	Current document definition.

B.2 GLOSSARY OF TERMS FOR DEVELOPING AND IMPLEMENTING A RISK ASSESSMENT METHODOLOGY FOR SOFTWARE SUPPORTABILITY.

Application Software

(AFOTECP5)
The software written by software support personnel, or purchased from a contractor, used directly in supporting ECSs. It is normally used for simulation, testing, and ECS code development.

Application Software (functional)

(AFR205X)
Those routines and programs designed by or for automatic data processing system users and customers to complete specific, mission-oriented tasks, jobs, or functions, using available automated data processing equipment and basic software. Application Software may be either general purpose packages, such as demand deposit accounting, payroll, machine tool control, etc., or specific application programs tailored to complete a single or limited number of user functions (for example, base level personnel, depot maintenance, aircraft, missile or satellite tracking, command and control, etc.). Except for general purpose packages acquired directly from software vendors or from the original equipment manufacturers, this type of software is generally developed by the user, either with in-house resources or through contract services.

Automated Software Development Tool

(AFOTECP5)
A component of System Software that assists in the design, implementation, documentation, and verification of ECS software.

Availability

(AFR800-14)
A measure of the degree to which an item is in the operable and commitable state at the start of the mission, when the mission is called for at an unknown (random) point in time. (MIL-STD-721)

(AFOTECP5)
The probability that a system is operating satisfactorily at any point in time when used under stated conditions.

Available Person Time (APT)

(CURRENT)
The software support person-months available for a particular software release computed as the product of the release duration

in months, the number of support personnel, and the percentage of the time those personnel are dedicated to the subject software release (versus shared across other releases or other software systems). This time includes overhead activity directly related to the subject release. The release duration is the release engineering completion date minus the release start date.

Baseline

(AFR300-15)
A configuration identification document or set of such documents formally designated and fixed at a specific time during a CPCI's life cycle. Baselines, plus approved changes to those baselines constitute the current configuration identification.

(ROWE)
A known reference used as a guide for further development activities.

Baseline Profile

(CURRENT)
See Baseline Software Supportability Profile.

Baseline Software Supportability Agreement

(CURRENT)
The software support concept and baseline software supportability profile agreed upon by the user (using command) and the supporter (supporting command).

Baseline Software Supportability Profile

(CURRENT)
The set of 27 pairs of numbers (or any subset) determined by specifying the (time to complete request, number of requests per unit time) pair for each request category. A request category is the triple (type, priority, complexity) where type is conversion, enhancement, or correction; priority is emergency, urgent, or normal; and complexity is high, medium, low. The time to complete request may be integrated as the time for a release, and specified requests become the content of the release.

Block Release

(CURRENT)
See Release.

Computer Program

(AFR800-14)
A series of instructions or statements in a form acceptable to an electronic computer, designed to cause the computer to execute an operation or operations.

Computer Resources

(AFR800-14)
The totality of computer equipment, computer programs, associated documentation, contractual services, personnel and supplies.

Configuration Control

(AFR300-15)
The systematic evaluation, coordination, approval or disapproval, and implementation of approved changes in the configuration of a CPCI after formal establishment of its configuration identification.

Configuration Item (CI)

(AFR300-15)
An item of ADPE that is designated for configuration management.

(AFR800-14)
An aggregation of equipment/software, or any of its discrete portions, which satisfies an end use function and is designated by the Government for configuration management. CIs may vary widely in complexity, size and type, from an aircraft or electronic system to a test meter or round of ammunition. During development and initial production, CIs are only those specification items that are referenced directly in a contract (or an equivalent in-house agreement). During the operation and maintenance period, any repairable item designated for separate procurement is a configuration item (AFR 65-3).

Configuration Management (CM)

(AFR300-15)
A management discipline that applies technical and administrative direction and surveillance to:

(1) Identify and document the functional and physical characterisitics of a configuration item
(2) Control changes to those characteristics
(3) Record and report configuration status.

Configuration Management Plan (CMP)

(AFR300-15)
A document which describes project responsibilities and procedures for implementing CM.

Configuration Management System (CMS)

(AFOTECP5)
A system applying technical and administrative direction and surveillance to identify and document the functional and physical characteristics of a configuration item; to control changes to those characteristics and to record and report change processing and implementation status.

Consistency

(CURRENT)
A measure of the extent the software products correlate and contain uniform notation, terminology, and symbology.

Conversion (Adaptive) MA

(CURRENT)
See Maintenance Type.

Corrective MA

(CURRENT)
See Maintenance Type.

Critical Issues

(AFOTECP)
Those aspects of a system's capability, either operational, technical, or other, that must be questioned before a system's overall worth can be estimated and that are of primary importance to the decision authority in reaching a decision to allow the system to advance into the next acquisition phase (DoD Directive 5000.3).

Data Item Description

(AFR[illegible])
A form which identifies and describes data required to be furnished by a contractor. The form ([illegible]) defines the content, preparation instructions, format and intended use of each data product. (AFR [illegible])

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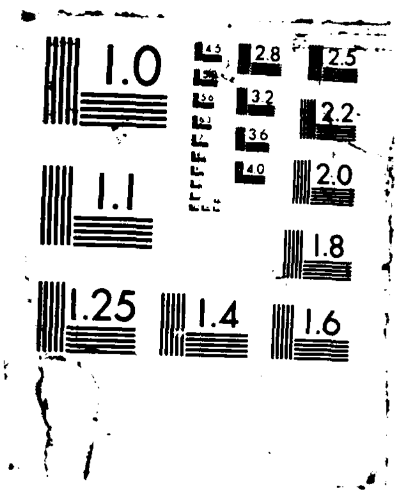
1.0
2.8
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2.2
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4.0
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1.1
1.8
1.25
1.4
1.6

Degree of Uncertainty

(ROWE)
That proportion of information about a total system that is unknown in relation to the total information about the system.

Descriptiveness

(CURRENT)
A measure of the extent that software products contain information regarding its objectives, assumptions, inputs, processing, outputs, components, revision status, etc.

Descriptive Uncertainty

(ROWE)
The absence of information about the completeness of the description of the degrees of freedom of a system.

Documentation

(AFOTECP5)
All of the written work describing operating and maintenance procedures for a system.

Documentation Consistency

(AFOTECP5)
A measure of the consistency in the information provided in support system documentation.

Documentation Descriptiveness

(AFOTECP5)
A measure of the descriptiveness of the information provided in support system documentation.

Documentation Modularity

(AFOTECP5)
A measure of the modular organization of information provided in support system documentation.

Documentation Simplicity

(AFOTECP5)
A measure of the ease of use and lack of complexity in the information provided in computer system documentation.

Embedded Computer Resources

(AFOTECP1)
Computer resources incorporated as integral parts of, dedicated to, required for direct support of, or for the upgrading or modification of major or less than major system(s) (excludes ADP resources as defined and administered under AFR 300 series) (USAF/RD/LE Policy letter, 13 October 1981).

Embedded Computer System (ECS)

(AFOTECP1)
a) A computer that is integral to an electromechanical system and that has the following key attributes:
   (1) Physically incorporated into a large system whose primary function is not data processing
   (2) Integral to, or supportive of, a larger system from a design, procurement, and operations viewpoint
   (3) Inputs include target data, environmental data, command and control, etc.
   (4) Outputs include target information, flight information, control signals, etc.

b) In general, an embedded computer system (ECS) is developed, acquired, and operated under decentralized management (DoD Directives 5000.1, 5000.2).

(AFOTECP5)
A computer that is integral to an electronic or electromechanical system (e.g., aircraft, missile, spacecraft, communications device) from a design, procurement, and operational viewpoint.

Emergency MA

(CURRENT)
See Maintenance Priority.

Enhancement (Perfective) MA

(CURRENT)
See Maintenance Type.

Estimation

(ROWE)
The assignment of probability measures to a postulated future event.

Estimator Uncertainty

(ROWE)
Uncertainty in measurement resulting from deliberate use of less complex measures such as central value estimates of dispersion and smoothing functions for time-dependent parameters.

Evaluation

(ROWE)
Comparison of an activity performance with the objectives of the activity and assignment of a success measure to that performance.

Evaluation Criteria

(AFOTECP1)
Standards by which achievement of required operational effectiveness/suitability characteristics or resolution of technical or operational issues may be judged. For full-scale development and beyond, evaluation criteria must include quantitative goals (the desired value) and thresholds (the value beyond which the characteristic is unsatisfactory) whenever possible (DoD Directive 5000.3).

Expandability

(CURRENT)
A measure of the extent that a physical change to information, computational functions, data storage, or execution time can be easily accomplished once the nature of what is to be changed is understood.

(AFOTECP5)
A measure of the ease with which the functional capability of computer hardware or software may be expanded.

Facility

(AFOTECP5)
The physical plant and the services it provides; specific examples are physical space, electrical power, physical and electromagnetic (TEMPEST) security, environmental control, fire safety provisions, and communications availability.

Feedback

(ROWE)
The return of performance data to a point permitting comparison with objective data, normally for the purpose of improving performance (goal-seeking feedback), but occasionally to modify the objective (goal-changing feedback).

Firmware

(AFOTECP1)
a) Computer programs and data loaded in a class of memory that cannot be dynamically modified by the computer during processing.
b) Hardware that contains a computer program and data that cannot be changed in its application environment.

Note 1. Computer programs and data contained in firmware are classified as software; the circuitry containing the computer program and data is classified as hardware (Data and Analysis Center for Software).

High Complexity MA

(CURRENT)
See Maintenance Complexity.

Historical Maintenance Profile

(CURRENT)
A histogram of data on software system releases, with the x-axis representing discrete ranges of (available) person-months per change and the y-axis representing the number of software system releases that fall into each x-axis discrete range. For purposes of analysis or illustration, the axes may be reversed.

Independent Verification and Validation (IV&V)

(AFOTECP1)
An independent assessment process structured to ensure that computer programs fulfill the requirements stated in system and subsystem specifications and satisfactorily perform the functions required to meet the user's and supporter's requirements. IV&V consists of three essential elements: independent, verification, and validation:

(1) Independent. An organization/agency which is separate from the software development activity from a contractual and organizational standpoint.
(2) Verification. The evaluation to determine whether the products of each step of the computer program development process fulfill all requirements levied by the previous step.
(3) Validation. The integration, testing, and/or evaluation activities carried out at the system/subsystem level to evaluate the developed computer program against the system specifications and the user's and supporter's requirements (AFR 88-14).

Individual Risk Evaluation

(ROWE)
The complex process, conscious or unconscious, whereby an individual accepts a given risk.

Initial Operational Capability (IOC)

(CURRENT)
That point in a system's life cycle when the agreed upon number of production systems has been delivered to the user (using command) for operational use.

Instrumentation

(CURRENT)
A measure of the extent that software products contain aids that enhance testing.

Interoperability

(AFOTECP5)
A measure of the degree to which computer hardware/software can interface to and operate with other similar computer hardware/software.

Low Complexity MA

(CURRENT)
See Maintenance Complexity.

Maintainability

(AFOTECP5)
The probability that a system out of service for maintenance can be properly repaired and returned to service in a stated elapsed time.

Maintenance Complexity

(CURRENT)
The general degree of difficulty to complete a maintenance request: high, medium, low.

High: An MA where changes are in requirements, design, code, and test; or greater than 10% of CSCI is affected; or several modules are affected by the change (global changes); or the technical nature of the change requires highly specialized personnel skills; or the level of effort by personnel is large.

Medium: An MA where changes are in design, code and test; or between 1% and 10% of CSCI is affected; or at least two modules are affected by the change (semi-local); or the level of effort by personnel is average.

Low: An MA where changes are isolated to only one unit (e.g., one module/compilation unit) of code; or no more than 1% of CSCI is affected; or the level of effort by personnel is minimal.

Maintenance Documentation

(AFOTECP5)
The documentation that describes the maintenance of computer system hardware and software.

Maintenance Priority

(CURRENT)
The criticality of the maintenance request in order to preserve mission readiness: emergency, urgent, normal.

Emergency: An MA requiring all available personnel's dedicated effort to correct the problem as soon as possible (e.g., 24 hours); MIL-STD-1679 severity code 1 or 2: mission termination or severe degradation.

Urgent: An MA requiring next "block release" turnaround; MIL-STD-1679 severity code 3: mission impact.

Normal: An MA not in the Emergency or Urgent categories; MIL-STD-1679 severity code 4 or 5: mission inconvenience.

Maintenance Profile

(CURRENT)
See Historical Maintenance Profile.

Maintenance Request Category

(CURRENT)
The identification of a maintenance request by specification of the maintenance priority, type, and complexity.

Maintenance Type

(CURRENT)
The type of maintenance actions required to complete a maintenance request: conversion, enhancement, correction.

Conversion (Adaptive) MA: Any change/effort to a software system which is initiated as a result of changes in the environment (e.g., hardware, system software) in which the software system must operate.

Enhancement (Perfective) MA: Any change, insertion, deletion, modification, or extension made to a software system to meet the evolving needs of the user.

Corrective MA: Any change which is necessitated by actual faults (induced or residual) in a software system.

Measured Risk Level

(ROWE)
The historic, measured, or modeled risk associated with a given activity.

Measured Uncertainty

(ROWE)
The absence of information about the specific value of a measurable variable.

Medium Complexity MA

(CURRENT)
See Maintenance Complexity.

Modularity

(CURRENT)
A measure of the extent that a logical partitioning of software products into parts, components, and/or modules has occurred.

Module

(AFR300-15)
A program unit that is discrete and identifiable with respect to compiling and combining with other units.

Normal MA

(CURRENT)
See Maintenance Priority.

Operational Effectiveness

(AFOTECP1)
The overall degree of mission accomplishment of a system used by representative personnel in the context of the organization, doctrine, tactics, threat (including countermeasures and nuclear threats), and environment in the planned operational employment of the system (DoD Directive 5000.3).

Operational Suitability

(AFOTECP1)
The degree to which a system can be satisfactorily placed in field use, with consideration being given availability, compatibility, transportability, interoperability, reliability, wartime usage rates, maintainability, safety, human factors, manpower supportability, logistic supportability, and training requirements (DoD Directive 5000.3).

Opinion Survey/Sampling

(ROWE)
Any procedure for obtaining by oral or written interrogation or both the views of any portion of the affected population regarding benefit levels expected, their utility, and/or relative importance. Typically, scientific sampling procedures would be used to maximize (for a given level of effort) the accuracy and precision of the results obtained.

Parametric Variation

(ROWE)
A technique for sensitivity analysis of any given model in which the values of parameters that are input to the model's calculation are systematically varied to permit observation of how such variation affects the model's output (especially ranking of alternatives).

Person-Months per Change (PMPC)

(CURRENT)
The available person-time divided by the total number of change requests for a software system release.

Personnel

(CURRENT)
See Support Personnel.

Personnel Skill Level

(CURRENT)
A subjective integer rating from 1 (lowest) to 5 (highest) of software support personnel experience, education, and specific task responsibility capabilities.

Probability

(ROWE)
A numerical property attached to an activity or event whereby the likelihood of its future occurrence is expressed or clarified.

Probability Distribution

(ROWE)
The representation of a repeatable stochastic process by a function satisfying the axioms of probability theory.

Probability of Occurrence

(ROWE)
The probability that a particular event will occur, or will occur in a given interval.

Probability Threshold

(ROWE)
A probability of occurrence level for a risk below which a risk agent is not long concerned with the risk and ignores it in practice (threshold of concern).

Product Baseline

(AFR300-15)
The initial approved product configuration identification.

Program Management Responsibility Transfer (PMRT)

(AFR800-14)
That point in time when the designated Supporting Command accepts program management responsibilities from the Implementing Command. This includes logistic support and related engineering and procurement responsibilities (AFR 800-4).

Program Support Tools

(AFOTECP3)
General debug aids, test/retest software, trace software/hardware features, use of compiler/link editor, library management/configuration management/text editor/display software tools.

Program Test Plan

(AFOTECP3)
Set of descriptions and procedures for how the program is to be (or can be, or has been) tested.

Propensity for Risk Acceptance

(ROWE)
An individual, subjective trait designating the degree of risk one is willing to subject oneself to for a particular purpose.

Quality Assurance (QA)

(AFR300-15)
All actions that are taken to assure that a development organization delivers products that meet performance requirements and adhere to standards and procedures.

Release

(CURRENT)
A version of a software system representing either the initial baseline configuration or an update to a previous version that incorporates a defined set of software change requests. Each release becomes a new baseline configuration.

Release Engineering Completion Date

(CURRENT)
The date when the software engineering activity for a release is complete. The software engineering activity includes configuration management, quality assurance, and software maintenance project phases of requirements, design, code, unit test, integration test, and operational test. Activity including "kit proofing," prom burning, and in general technical order modifications which typically occur between engineering completion and field implementation (distribution) is not included.

Release Field Date

(CURRENT)
The date when a software system release is officially distributed and implemented in the field for operational use.

Release Id

(CURRENT)
A unique identifier for a software system release.

Release Start Date

(CURRENT)
The date when major analysis activity related to a specified release begins for which software support resources are required.

Reliability

(ROWE)
The probability that the system will perform its required functions under given conditions for a specified operating time.

Risk

(ROWE)
The potential for realization of unwanted, negative consequences of an event.

Risk Acceptance

(ROWE)
Willingness of an individual, group, or society to accept a specific level of risk to obtain some gain or benefit.

Risk Acceptance Function

(ROWE)
A subjective operator relating the levels of probability of occurrence and value of a consequence to a level of risk acceptance.

Risk Acceptance Level

(ROWE)
The acceptable probability of occurrence of a specific consequence value to a given risk agent.

Risk Acceptance Utility Function

(ROWE)
The profile of the acceptability of the probability of occurrence for all consequences involved in a risk situation for a specific risk agent.

Risk Agent

(ROWE)
See Valuing Agent.

Risk Assessment

(AFR205X)
A detailed study of the vulnerabilities, threats, likelihood, loss or impact, and theoretical effectiveness of security measures. The results of a risk assessment may be used to develop security requirements and specifications.

(ROWE)
The total process of quantifying a risk and finding an acceptable level of that risk for an individual, group, or society. It involves both risk determination and risk evaluation.

Risk Assessment Methodology for Software Supportability (RAMSS)

(CURRENT)
A method of determining the disparity between the acceptable risk (determined from the support concept, baseline software supportability profile, and historical maintenance profile) and the measured risk (determined from a conversion of the software supportability evaluation metrics).

Risk Aversion

(ROWE)
The act of reducing risk.

Risk Baseline

(CURRENT)
The risk probability density function and the associate magnitude of consequence for the potential negative outcomes.

Risk Consequence

(ROWE)
The impact to a risk agent of exposure to a risky event.

Risk Conversion Factor

(ROWE)
A numerical weight allowing one type of risk to be compared to another type.

Risk Determination

(ROWE)
The process of identifying and estimating and magnitude of risk.

Risk Estimation

(ROWE)
The process of quantification of the probabilities and consequence values for an identified risk.

Risk Evaluation

(ROWE)
The complex process of developing acceptable levels of risk to individuals or society.

Risk Evaluator

(ROWE)
A person, group, or institution that seeks to interpret a valuing agent's risk for a particular purpose.

Risk Identification

(ROWE)
The observation and recognition of new risk parameters, or new relationships among existing risk parameters, or perception of a change in the magnitude of existing risk parameters.

Risk Profile Baseline

(CURRENT)
The measure of information and/or requirements which serve as the zero reference against which negative (and positive) outcomes can be determined.

Risk Reduction

(ROWE)
The action of lowering the probability of occurrence and/or the value of a risk consequence, thereby reducing the magnitude of the risk.

Risk Reference

(ROWE)
Some reference, absolute or relative, against which the acceptability of a similar risk may be measured or elated; implies some overall value of risk to society.

Sensitivity Analysis

(ROWE)
A method used to examine the operation of a system by measuring the deviation of its nominal behavior due to perturbations in the performance of its components from their nominal values.

Simplicity

(CURRENT)
A measure of the extent that software products reflect the use of singularity concepts and fundamental structures in organization, language, and implementation techniques.

Simulation

(AFR800-14)
The representation of physical systems or phenomena by computers, models or other equipment.

Site

(CURRENT)
A software support site, or particular location, where software support activity is being accomplished. Includes sites such as the Air Logistics Centers (ALCs).

Site Survey Form

(CURRENT)
The data collection form used during the software support site visits to collect background, evaluation, and maintenance release data. See appendix C.

Software

(AFOTECP1)
A set of computer programs, procedures, and associated documentation concerned with the operation of a data processing system.

(CURRENT)
The programs which execute in a computer. The data input, output, and controls upon which program execution depends and the documentation which describes, in a textual medium, development and maintenance of the program.

Software Change Request

(CURRENT)
An official request that could involve a change to a software system. Such requests include problem report, enhancement requirement, modification request, or any other form that is officially tracked by a configuration management function.

Software Configuration Management

(CURRENT)
A discipline applying technical and administrative direction and surveillance to 1) identify and document the functional and physical characteristics of a configuration item, 2) control changes to those characteristics and 3) record and report change processing and implementation status.

Software Delivery

(CURRENT)
That point in the software life cycle when the software support function assumes responsibility for the "next" set of configuration changes to the software (e.g., next block release). This point is logically no later than PMRT, but could be as early as IOC. This applies when a contractor or government agency assumes the software support function.

Software Error

(CURRENT)
The human decision (inadvertent or by design) which results in the inclusion of a fault in a software product.

Software Fault

(CURRENT)
The presence or absence of that part of a software product which can result in software failure.

Software Life Cycle Process Management

(CURRENT)
The policy, methodology, procedures, and guidelines applied in a software environment to the software development and support life cycle activities.

Software Maintainability

(AFOTECP1)
The ease with which software can be changed in order to:
(1) Correct errors
(2) Add/modify system capabilities through software changes
(3) Delete features from programs
(4) Modify software to be compatible with hardware changes.

(CURRENT)
A quality of software which reflects the effort required to perform software maintenance actions.

Software Maintenance

(CURRENT)
Those actions required for:
(1) Correction - Removal, correction of software faults
(2) Enhancement - Addition/deletion of features from the software
(3) Conversion - Modification of the software because of environment (data hardware) changes.

Software Maintenance Environment

(CURRENT)
An integration of personnel support systems and physical facilities for the purpose of maintaining software products.

Software Maintenance Measures

(CURRENT)
Measures of software maintainability and environment capabilities to support software maintenance activity.

Software Maintenance Project Management

(CURRENT)
The software life cycle process management applied during the support phase for the software to accomplish specific software maintenance tasks which derive from software problem reports or change requests.

Software Management

(CURRENT)
The policy, methodology, procedures, and guidelines applied in a software environment to the software development/maintenance activities. Also, those personnel with software management responsibilities.

Software Reliability

(CURRENT)
A quality of software which reflects the probability of failure free operation of a software component or system in a specified environment for a specified item.

Software Portability

(CURRENT)
A quality of software which reflects the effort required to transfer the software from one environment (hardware and system software) to another.

Software Support Facility (SSF)

(AFOTECP5)
The facility which houses and provides services for the support systems and personnel required to maintain the software for a specific ECS.

Software Support Personnel

(CURRENT)
See Support Personnel.

Software Support Resources

(CURRENT)
The totality of personnel, systems, physical facilities, and calendar time that are used/consumed during a software support release effort.

Software Supportability

(CURRENT)
A measure of the adequacy of personnel, resources, and procedures to facilitate:

(1) Modifying and installing software
(2) Establishing an operational software baseline
(3) Meeting user requirements.

Software Supportability Evaluation

(CURRENT)
An evaluation to derive a measure of how well a software system can be supported. (See Software Supportability.)

Software Supportability Evaluation Metrics

(CURRENT)
The closed-form questionnaire scores for each software supportability characteristic in a software supportability evaluation as well as the values computed by cumulating lower level scores.

Software Supportability Magnitude Of Risk Consequence

(CURRENT)
The level of impact to a software user or supporter as a result of the risk level of a software supportability negative outcome.

Software Supportability Negative Outcome

(CURRENT)
Any outcome for which the software support resources are not adequate to accomplish required software support.

Software Supportability Risk

(CURRENT)
The probability at a given point during the software support phase that the software maintenance activity specified by a baseline software supportability profile can not be accomplished with the available software support resources.

Estimated Software Supportability Risk: An estimate of the software supportability risk determined by the area under an historical maintenance profile curve. The area is the part under the curve to the "right" of the subject software's available person-months per change value as computed from the estimated software support concept and baseline software supportability profile. Numerically, this area is the number of software system releases in the historical maintenance profile with an available person-months per change greater than the subject software's computed person-months per change divided by the total number of software system releases in the historical maintenance profile.

Acceptable Software Supportability Risk: The estimated software supportability risk which is agreed upon by the user (using command) and supporter (supporting command) as a result of the baseline software supportability agreement.

Evaluated Software Supportability Risk: An approximation to the software supportability risk computed from the software supportability evaluation metrics. The computation is derived from one or more of the three models described in section 4: simple linear conversion, linear regression, and factor analysis regression.

Measured Software Supportability Risk: See Evaluated Software Supportability Risk.

Software Supportability Risk Agent Acceptance Level

(CURRENT)
The software supportability risk level which is acceptable to a risk agent.

Software Supportability Risk Level.

(CURRENT)
The potential for realization of a software supportability negative outcome.

Software System

(CURRENT)
A set of software (specifications, programs, and data) which constitutes a well-defined major function or group of functions.

Typical systems include avionics OFP, ground based communications, missile guidance, simulation, threat generator, ATE, and electronic warfare.

Software System Type

(CURRENT)
One of seven classifications of a software system's primary functional mission: ATD, ATE, C-E, EW, OFP, SIM, SUP.

ATD: Aircrew Training Device or Operational Flight Trainer for training and support of an operational system, usually in the form of a mockup simulator.

ATE: Automatic Test Equipment software to support the testing of hardware units under test (UUT), create and maintain the environment where the test software may be used, or prepare/analyze/maintain test software.

C-E: Communications-Electronics software for command and control, communications, surveillance and warning, air traffic control, intelligence, and other related functions.

EW: Electronic Warfare software that involves the use of electromagnetic energy and performs functions either separate or integral to a larger airborne or ground system.

OFP: Operational Flight Program software/firmware that is integral to an onboard aircraft computer system including navigation, flight control, fire control, weapon delivery, electronic engine control, and heads-up display.

SIM: Simulation Software not included as part of the ATD, including simulation models.

SUP: Support Software including application support software and system support software not included in any other category.

Specification

(AFR300-15)
A document that describes the requirements for the development or acquisition of ADPE and/or software.

Source Code

(CURRENT)
The form of the program code in its source language.

Standards

(AFOTECP3)
Procedures, rules, and conventions used for prescribing disciplined program design and implementation.

Subjective Probabilities

(ROWE)
The assignment of subjective weights to possible outcomes of an uncertain event where weights assigned satisfy axioms of probability theory.

Support Concept

(CURRENT)
The software support concept usually specified as part of the CRISP and OS/CMP. Also includes that part of the support concept necessary to establish the acceptable risk from a baseline software supportability profile: standard release duration, number of support personnel, average skill level, percentage of personnel dedicated to releases, support facility, etc.

Support Facility

(CURRENT)
The physical facility resources that must be available for the software support resources to accomplish a specific task(s).

Support Personnel

(CURRENT)
A general term for personnel (military, DoD civilian, or DoD contractor) whose skills are necessary to directly support mission critical system software maintenance. Includes but is not limited to management, technical, non-technical support, and contractor personnel.

Support System

(AFOTECP5)
Any automated system used to change, test, or manage the configuration of ECS software and associated documentation. Includes but is not limited to Host Processor, Software Bench, Laboratory-Integrated Test Facility, Operational-Integrated Test Facility, and Configuration Management System.

Support System Facility

(AFOTECP5)
The facility resources that must be available for the software support resources to accomplish a specific task(s).

System Software

(AFOTECP5)
All of the software that is part of the software support facility computer system. It is never or seldom accessed directly by software support facility personnel; it controls the processing of application software. It includes the Operating System, Source Code Editor, Language Translator, Link Editor/Loader, Librarian/File Manager, Data Base Manager, and Automated Software Development Tool.

Threshold

(ROWE)
A discontinuous change of state of a parameter as its measure increases. One condition exists below the discontinuity, and a different one above it.

Time to Complete Maintenance Request (TC)

(CURRENT)
The calendar time from receipt of the maintenance request by the support control group until the request has been accepted as part of an operational system software configured release. (This does not mean the configuration is released or distributed, and this time does not include this additional delay, if any.)

Uncertainty

(ROWE)
The absence of information; that which is unknown.

Urgent MA

(CURRENT)
See Maintenance Priority.

User

(AFR205X)
Any persons (organizations) having access to an automatic data processing system via communication through a remote device or allowed to submit input to the system through other media (for example, tape or card decks). (Does not include those persons or organizations defined as customers.)

Valuing Agent

(ROWE)
A person or group of persons who evaluates directly the consequence of a risk to which he is subjected. A risk agent.

Verification/Validation (of computer programs)

(AFR800-14)
The process of determining that the computer program was developed in accordance with the stated specification and satisfactorily performs, in the mission environment, the function(s) for which it was designed.

Weight (structured value analysis)

(ROWE)
The relative importance of terms in a model expressed as a decimal fraction; weights for a set of terms add to unity.

Weighting Factor

(ROWE)
A coefficient used to adjust variable accuracy to a subjective evaluation; these factors are usually determined through surveys, Delphi sessions, or other formats expressing social priorities.

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